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ORIGINAL ARTICLES.

I.—Eocene Corals from the Fly River, Central New Guinea.

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(PLATES XXI-XXII.)

(*Concluded from the November Number, p. 488.*)

Actinacis, D'Orbigny, 1849.

Actinacis maitlandi,[1] n.sp. (Pl. XXI, Figs. 2, 3.)

Diagnosis.—Corallum massive and probably nodular. Corallites polygonal, often pentagonal, and, where the walls are not well defined, appear circular. Calices from 2 to 3 mm. in diameter; the width of cœnenchyma separating them varies from ·5 to 2 mm. Septa twenty-four in number, subequal; the trabeculæ are distinct in some and in others fused together. Pali rounded; they occur in three crowns, the primary pali being larger than the others. They are sometimes quite separate from the septa, and sometimes completely fused with the septal ends. Together with the columella they occupy a space equal to one-third of the diameter of the calyx. Columella fairly large, though somewhat irregularly developed. Occasionally it is so small as to appear papilliform, but it is generally clearly fascicular.

Dimensions.—Diameter of corallites, 2·6–3 mm.; distance of calicinal centres, 3–5 mm.

Figures.—Pl. XXI, Fig. 2*a*, thin transverse section; × 6 diam. Fig. 2*b*, polished surface of same; × 6. Fig. 3, thin transverse section of another specimen; × 6 dia.

Affinities.—This species is represented in the collection by three specimens (Nos. 20, 26, 37). It resembles the type species *A. martiniana*, Orb. (1849, p. 11), in the number and arrangement of septa, but the calices are nearly twice as large and the cœnenchyma is much more sparse. It approaches more nearly to the *A. remesi*. Felix (1903, pp. 567–70), but the calices are greater than those of the latter and the cœnenchyma is also considerably less. Trauth (1911, p. 79) has described a new species, *A. retifera*, which has round or sub-polygonal calices, some of which equal *A. maitlandi* in size. The cœnenchyma, however, differs both in amount and character, and the columella is rudimentary. These species are all Cretaceous. Of the Kainozoic species, *A. noetlingi*, Dalton (1908, p. 622, pl. liv, fig. 1), from the Miocene of Burmah, resembles our

[1] After Mr. A. Gibb Maitland, one of the geological pioneers in British New Guinea.

species in calicular characters; but its calices are much more widely separated, the centres being from 10 to 11 mm. apart, and the corallum is dendroid.

An Eocene species, *A. digitata*, from Borneo, has been described by Fritsch (1875, p. 129, pl. xvii, fig. 7); it differs very considerably from *A. maitlandi*; its calices are smaller, the pali are more prominent and regularly arranged around a small columella, which on the surface appears styliform; the corallum, moreover, is dendroid.

Actinacis sumatraensis (Tornquist), 1901. (Pl. XXI, Fig. 1.)

Neostroma sumatraensis, Tornquist, 1901: "Ueber mesozoische Stromatoporiden," Sitz. k. preuss. Akad. Wiss., 1901, pp. 1117–20, figs. 1–5.
Actinacis sumatrensis, Gerth, 1909: "Echte und falsche Hydrozoen aus niederländisch-Indien," Sitz. Niederrhein. Ges. Natur. u. Heilkunde zu Bonn, Abt. A, 1909, pp. 21–3.

This species is represented by one specimen, No. 14. It agrees closely with the Sumatran Cretaceous species *A. sumatraensis* (Tornquist), though the septa in the latter are thinner, longer, and more irregular, while the calices are slightly larger and closer together. In *A. cymatoclysta* (Felix, 1906, p. 43, pl. iii, figs. 4, 4*a*) the calices are almost of the same size and shape, but the primary septa at least reach the columella, which is feebly developed, though the pali are distinct.

Porites, Lamarck, 1816.

Porites deshayesana, Mich. (Pl. XXII, Figs. 2*a*, *b*.)

Porites deshayesana, Mich., 1844, p. 164, pl. xlv, fig. 4.

The collection includes one specimen (No. 23) of a *Porites* which agrees in nearly all respects with the above species. If, however, Bernard (1906, p. 109) were right that the calices of *P. deshayesana* are less than 1 mm. in diameter, it would differ in that important respect. Bernard states that his estimate of the dimensions is based on Michelin's original figure, in which, according to our measurements, the corallites are shown as at least 1·5 mm. in diameter. They thus agree with those of the New Guinea *Porites*. The character of the septa are shown by the accompanying drawings of three corallites from a section (see Text-figure).

Porites deshayesana, Mich., var. *inequisepta*, n. var. Transverse sections of three corallites. Upper Fly River, New Guinea.

The septa appear to be thicker and more unequal in size than in the typical form of the species. Accordingly we feel bound on that character to separate this coral as a distinct variety and name it var. *inequisepta*.

Amongst other Eocene species this *Porites* agrees by its ill-defined columella and indistinct wall with *Porites heberti*, Ed. & H., sp. (1850,

p. 39; Hist. Nat. Cor., vol. iii, p. 187), but in that species the septa are more equal and the corallites are 3 mm. in diameter.

P. belli, Greg. (1900, p. 223), from the Miocene or later rocks of Christmas Island, is an allied species, but has better developed walls.

MONTIPORA, Quoy & Gaimard, 1833.

Montipora antiqua, n.sp. (Pl. XXII, Figs. 1*a*, *b*.)

Diagnosis.—Corallum massive. Corallites long and thin. Calices circular and shallow; their diameter is about half the width of the distance between the calicinal centres. The calices are surrounded by a zone of porous tissue. The corallites are separated by short straight lines of more compact cœnenchyma, which gives the corallum in section the appearance of being composed of prismatic corallites. Septa twelve in number; they consist only of spines. Columella conspicuous. Pali absent.

Figures.—Pl. XXII, Fig. 1*a*, photograph of a polished transverse section (No. 36); × 3 diam. Fig. 1*b*, polished vertical section of the same specimen; × 3 diam.

Affinities.—This interesting coral has the structure well preserved on the surface which was first polished. A microscopic section was cut from the lower part, but the material there has been altered, and the intimate structure is less satisfactorily shown. The coral, owing to its spiny septa and massive porous cœnenchyma, belongs to the Montiporidæ.

Among the living species of *Montipora* this species is nearest to those which, like *M. hirsuta*, Bernard (1897, p. 164, pl. xxxiv, fig. 16), have a columella and the calices separated by a perforate wall that rises, as in *M. calcarea* (Bernard, 1897, p. 59, pl. xxxii, fig. 13), to a distinct ridge. If these two characteristics were always associated, as in *M. antiqua*, species in which they are present should be separated as a distinct genus or subgenus. The recent species that have a columella occur in each of Bernard's five sections of the genus; for among the glabrous group it occurs in *M. exserta*, Quelch; in the glabro-foveolate in *M. spatula*, Bern.; in the foveolate in *M. calcarea*, Bern. (though no columella is shown in Bernard's figure of that species, 1897, pl xxxii, fig. 13); in the papillate in *M. verrucosa*, Lam., *M venosa*, Ehr. (not shown in Bernard's figure, pl. xxxii, fig. 16), and *M. spumosa*, Lam.; and in the tuberculate in *M. friabilis*, Bern., *M. ellisi*, Bern., *M. efflorescens*, Bern., *M hirsuta*, Bern., and *M. incognita*, Bern. As these five groups are based on so variable a feature as surface ornamentation they appear artificial, and the presence of a columella and of the immature wall in the cœnenchyma are probably more constant and reliable characteristics. Milne Edwards and Haime in their diagnosis of *Montipora* say that it has neither columella nor pali.[1] But Bernard has shown that a columella is present in some recent *Montipora*, such as *M. ellisi* and *M. floreseens*. Though it is inconsistent with the practice throughout the rest of the Madreporaria to leave in one genus species with and species without

[1] Duncan, by an obvious slip, wrote "with columella and pali", whereas it should probably have been "without columella and pali".

a columella, as that course has been adopted for the recent *Montiporæ* it seems advisable to follow it.

The genus *Montipora* is confined in range to the western Pacific, Indian Ocean, and Red Sea. A fossil specimen has been recorded from the raised beaches of the Gulf of Suez (Gregory, 1906, p. 117), and a living species from the Pliocene of Borneo (Felix, 1913, p. 326); but otherwise it appears to be unknown fossil. The occurrence of this Eocene Montiporid is of interest, as it throws light on the disputed question as to the affinities of the family. According to Dana (1848, p. 490), *Montipora* (which he calls *Manopora*) is a degenerate *Madrepora*. This view has also been accepted by Bernard (1897, vol. iii, p. 12). Milne Edwards and Haime, on the other hand, regarded *Montipora* as a Poritoid with an abundant cœnenchyma; and this view has been adopted by Duncan. The essential difference between the Poritidæ and the Madreporidæ appears to be the character of the septa. In *Madrepora* they are lamellar; in the Poritidæ they are reduced to irregular trabeculæ. In this characteristic *Montipora* is more similar to *Porites* than to *Madrepora*. Bernard argues that the characters which give a trabecular character to the cœnenchyma of *Montipora* are shown by his investigations to be secondary structures. It might therefore be inferred that the trabecular nature of the septa is also secondary. But in the Eocene *Montipora* the septa are spines and not lamellæ; this characteristic was fully developed in the earliest known species; and that fact supports the view that the Montiporidæ are more nearly related to the Poritidæ than to the Madreporidæ.

The Age and Relations of the Fauna.

The affinities of this fauna as a whole, with the exception of the one Cretaceous species, are Eocene, but geographically it is too isolated to be satisfactorily referred to the precise subdivision of that system. Mr. R. B. Newton, who is kindly describing the associated foraminiferal limestones, tells us that their age is probably Lutetian (Middle Eocene); and the coral fauna is consistent with that opinion.

It has been long known that New Guinea includes a rich and varied series of Kainozoic deposits, which range from the Eocene to the Pleistocene. They include thick beds of foraminiferal limestone which in Dutch New Guinea form precipices (Rawling, 1911, p. 244, and Wollaston, 1914, pp. 257, 265) that have been described as the loftiest in the world. The rocks have a general trend east and west, and they are represented by similar rocks on the western islands of Malaysia.

The best known of the Kainozoic deposits of New Guinea are the foraminiferal beds, which include Eocene limestones with *Nummulites* and *Alveolina*, Miocene orbitoidal limestone, and in the Upper Pliocene or Pleistocene widespread foraminiferal oozes or marls (e.g. Schubert, 1910, p. 326), which indicate an extensive subsidence in very recent geological times. A valuable summary of the information regarding these foraminiferal limestones and full references to

the literature on them has been recently given in the memoir by Mr. R. B. Newton (1916).

In British New Guinea the first known Kainozoic beds were the Pliocene and Pleistocene. A review of the earlier literature was given by Mr. Robert Etheridge, fil. (in Thomson, 1892, pp. 208–15, and in Jack & Etheridge, 1892, pp. 696–7). At that date the beds best known were those in the neighbourhood of Yule Island and the adjacent parts of the coasts of south-eastern New Guinea; and they are Pliocene and Pleistocene in age. Mr. Gibb Maitland refers (1893, p. 62) in his valuable memoir on the Geology of British New Guinea to the occurrence of the raised coral reefs ranging from sea-level to the height of 2,000 feet; and he remarks that there is no reliable evidence as to their geological age. Subsequently Eocene beds were recorded from Dutch New Guinea, as in the Wilhelmina Mountains (Martin, 1911) and at Triton Bay; and also in German New Guinea, as in the Torricelli Mountains and Humboldt Bay (Rutten, in Wichmann, 1914, pp. 42–3), in Celebes (Bücking, 1902), in Sumatra (Volz, 1904, p. 89), and in Java (Martin, 1900, 1915, etc.). The Eocene foraminiferal limestones no doubt represent the great Nummulitic limestone of the Mediterranean and Southern Asia, for some of them are referred to the Middle Eocene. Beneath this marine series there are in many places continental deposits sometimes containing coal (as in Java, Martin, 1900, p. 243) and sometimes yielding oil. Owing to this association of land and marine deposits it is natural to find that shallow-water beds with reef-building corals frequently occur in the Eocene beds. Thus Bücking (1904, pp. 177, 149) quotes Koperberg as authority for the existence of coral limestones in Celebes up to 1,000 metres above the sea, and Retgers for the occurrence of corals with *Nummulites* at Malawa in Celebes. Comparatively little has, however, been published on the Eocene corals of this Archipelago. The most important communication is that by Fritsch (1875) on the Eocene corals of Borneo. Martin (1881, pp. 73, 82–3) quotes Pleistocene corals from Southern New Guinea, and refers to the occurrence of corals with the Old Miocene limestone; and as he says these limestones include *Alveolina* they may be Eocene, but he does not describe the corals. The lists from Sumatra by Volz (1904, pp. 89, 90) include many species of corals from the Upper Pliocene, but none from the Eocene. The Miocene and Pliocene coral faunas are known from Java (Reuss, 1866, and Felix, 1913), Sumatra (Volz, 1904, p. 90), and from the collection by Dr. Andrews at Christmas Island (Gregory, 1900).

The nearest well-known fauna of Eocene reef corals is that described by Duncan (1880) from Sind. There is a certain generic resemblance between the two faunas, but some of the most typical of the Sind genera are absent from the New Guinea collection; and we have been able to refer only one of the New Guinea Eocene corals to previously known species.

The corals therefore strongly confirm the opinions of Martin (1915, p. 222) and Oppenheim (1901, p. 309) as to the remarkable isolation of the Eocene fauna of Malaysia. The presence of the

Montipora is very significant in this connexion, for the Montiporids are unrepresented either in Sind or in Europe. A fossil *Montipora* has been recorded from the Pleistocene raised beaches of the Red Sea (Gregory, 1898, p. 117), and it would thus appear probable that the Montiporids originated in the Western Pacific, that they had not reached India even in Miocene times, and that they had reached the Red Sea in the Pleistocene.

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EXPLANATION OF PLATES XXI–XXII.

PLATE XXI.

1. *Actinacis sumatraensis* (Tornquist). No. 14. Part of transverse section of corallum, × 6 diam.
2. *A. maitlandi*, n.sp. No. 20. Fig. 2*a*, part of transverse section of corallum, × 6 diam.; Fig. 2*b*, part of polished surface of corallum, horizontal section, × 6 diam.
3. *A. maitlandi*, n.sp. No. 37. Part of transverse section of corallum, × 6 diam.
4. *Kobya hemicribriformis*, n.sp. No. 35. Part of polished surface of corallum, nat. size.

PLATE XXII.

1. *Montipora antiqua*, n.sp. No. 36. Fig. 1*a*, part of polished surface of corallum, horizontal section, × 3 diam.; Fig. 1*b*, part of polished surface of same specimen, vertical section, × 3 diam.
2. *Porites deshayesana*, Mich., var. *inequisepta*, n.var. No. 23. Fig. 2*a*, part of surface of corallum, × 10 diam.; Fig. 2*b*, part of surface of corallum, × 2½ diam.

The locality of all the specimens is the Upper Fly River, New Guinea. The species figured are from the Eocene, and probably Middle Eocene, except *Actinacis sumatraensis*, which is Upper Cretaceous.

NOTE.—Since the first part of this paper was printed we have received from Mr. F. Chapman a description of Aquitanian limestones with *Lepidocyclina* and *Heterostegina*, which were collected at Bootless Inlet, British New Guinea, by Mr. J. E. Carne (Chapman, F. 1914. Description of a Limestone of Lower Miocene Age from Bootless Inlet, Papua. Journ. Proc. Roy. Soc. N.S. Wales, vol. xlviii, pp. 281–301, pls. vii–ix).

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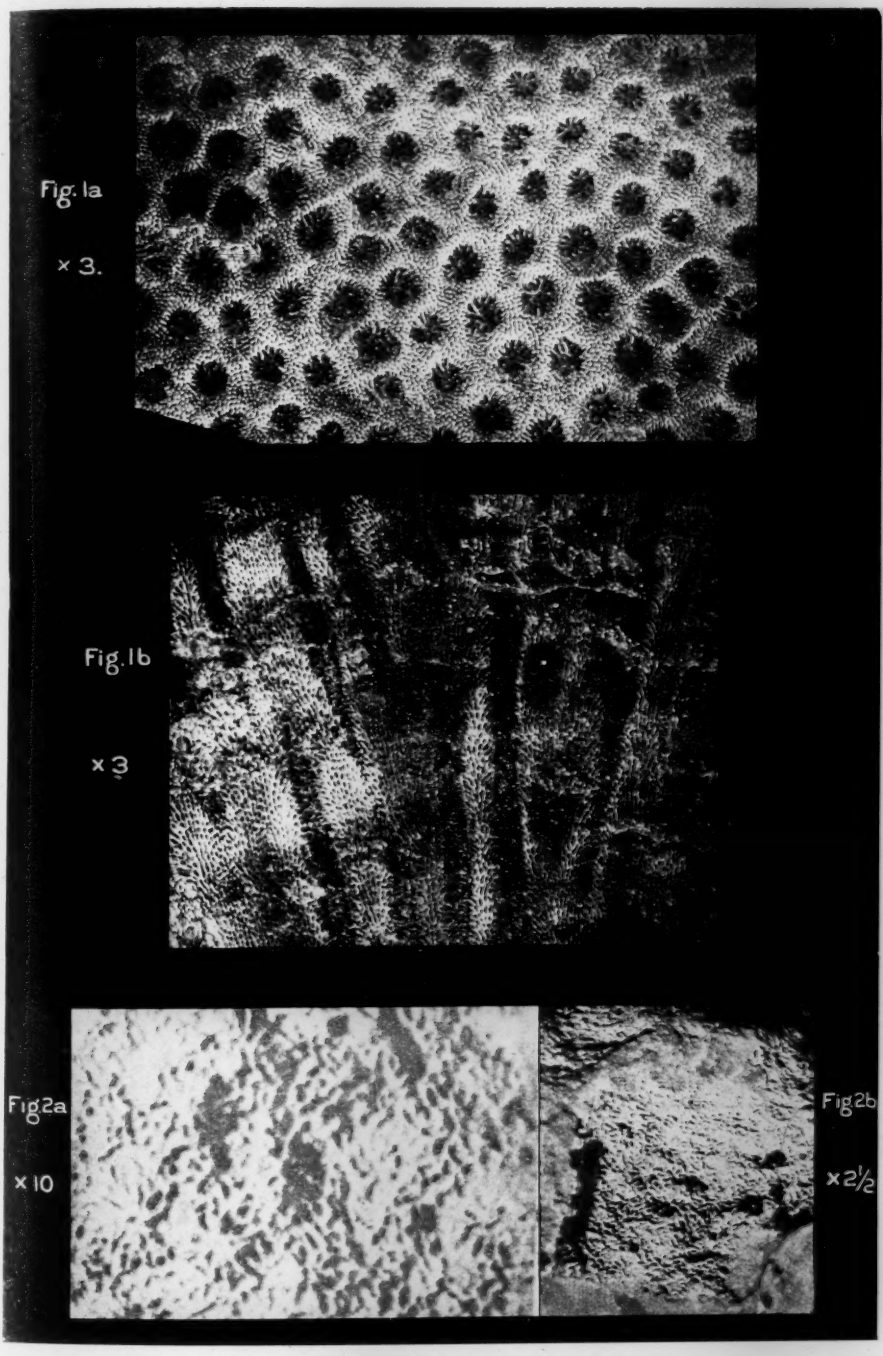
II.—THE CAUSE OF THE ICE AGE AND GLACIER FLUCTUATIONS.

By R. M. DEELEY, M.Inst.C.E., F.G.S.

THE fluctuations which take place from time to time in the lengths of glaciers are extremely interesting to the glaciologist; for there are good reasons for believing that the meteorological conditions which give rise to the lesser oscillations of glaciers are generally of the same character as those which produced the great secular changes of climate which occurred in past ages.

At the present time there are two theories purporting to account for the more important glacier fluctuations. The one assumes that they are due to increased precipitation per square yard, whilst the other attributes the phenomena to a general lowering of the temperature of the atmosphere, the precipitation per square yard remaining practically unaltered. In the case of the latter theory, the variation in the amount of ice formed is considered to be due to the lowering of the snow-line and consequent increase in the size of the *névé* areas.

It is evident that within historic times changes of climate have occurred, for we have records of very considerable advances and



Photos by S. Fingland. Gregory & Trench.

EOCENE CORALS, NEW GUINEA.

Montipora. *Porites.*

retreats of glaciers in many parts of the world, whilst during Pleistocene time very much more pronounced oscillations are known to have taken place. The question as to whether the prehistoric great oscillations of climate, and the less pronounced historic oscillations, have been due to similar climatic changes is one of considerable interest. That glacialists are by no means all of one opinion on this point may be gathered from the recent literature of the subject.

The very existence of glaciers depends upon both temperature and amount of precipitation; for the presence of glacier ice results from the fact that over certain areas more snow falls in the winter than the summer heat can melt, and as the ice thus collected is a very viscous liquid it slowly flows to lower levels and reaches altitudes where the temperature is sufficiently high to melt it. In glaciers we thus always have *alimentation* and *ablation* areas.

Within the limits of height reached by mountains, as we rise in the atmosphere, the temperature falls, and as a glacier is ascended the temperature falls about 1° C. for every 140 metres of vertical rise.[1] On this account a greater proportion of the precipitation comes down as snow at high levels than is the case at lower levels. However, the precipitation per square yard varies considerably with the height and aspect of the mountain mass. Thus it has been shown that on the declivities of the Aiguille du Gouter the precipitation falls off rapidly as we ascend or descend from the level of 2,550 metres. Indeed, the precipitation not only varies greatly from place to place on a mountain range, but when the precipitation is in the form of snow it is blown to great distances, or slides off the slopes and collects at low levels in great masses. In the Northern Hemisphere, slopes and valleys facing south are much more exposed to the sun's rays than are those having a northerly aspect, and the winds reaching them are generally warmer. There is, consequently, no regular continuous snow-line, i.e. a regular level above which some of the winter snow survives the heat of summer and below which all the snow of winter is melted away during the summer.

Although the snow-line is a very irregular feature as regards height, in the case of the majority of glaciers it will be found that snow-lines can be drawn across them and their tributaries, above which some of the snow of winter does not entirely melt each year, and below which not only is all the snow melted away but some of the ice is melted as well. Such a snow-line cuts the glacier into two portions, of which the upper portion is the *alimentation* area, whilst the lower portion is the *ablation* area. If the meteorological conditions remained invariable from year to year, then the glacier would always appear to be in the same condition during the corresponding months of each year.

If the precipitation of snow should increase per square yard, then the snow-line would be lowered, the *névé* would get thicker and larger in area, and as a result the ablation area of the glacier (the tongue portion) would have to grow longer, and if possible wider, so as to admit of the greater quantity of ice coming down being melted

[1] Hans Hess, *Die Gletscher*, 1904, p. 210.

away. On the other hand, if the total precipitation per square yard remained unaltered, and the snow-line were lowered owing to a colder atmosphere, then the snow collected in the larger *névé* (alimentation area) would be greater in quantity and the ablation area would have to be increased by the lengthening and broadening of the tongue (ablation) portion.

The Figure is a map of a small glacier showing the snow-line. A is the alimentation area, and B is the ablation area. These two areas of any glacier must be properly proportioned the one to the other.[1] Taking a large number of glaciers the average area of the alimentation region is about three times that of the ablation region. A comparatively small change in the position of the snow-line, in the case of such a glacier as is shown in the Figure, would cause a considerable retreat or advance of the glacier tongue.

Map of a small glacier showing (A) the alimentation area and (B) the ablation area.

Although it is clear that either of the theories here considered explains how glacier variations may occur, they are so fundamentally different in principle that it is of the utmost importance that they should both receive very careful consideration when dealing with glacier fluctuations, large or small. They may be referred to as the *precipitation* and *temperature* theories respectively.

Any increase in the precipitation per square yard requires an increased rate of evaporation over the water-covered areas, and to obtain this a hotter sun is required. Such an increase of temperature would tend to raise the snow-line, whilst the increased precipitation of snow would tend to lower it. On this point[2] Tyndall remarks:

[1] *Die Gletscher*, 1904, p. 84.

[2] *Heat considered as a mode of motion*, chap. vi.

"So natural was the association of ice and cold, that even celebrated men assumed that all that is needed to produce a great extension of our glaciers is a diminution of the sun's temperature. Had they gone through the foregoing calculations they would probably have demanded *more* heat instead of less for the production of a glacial epoch. What they really needed were *condensers* sufficiently powerful to congeal the vapour generated by the heat of the sun." According to the temperature theory the *condensers* which Tyndall demands are furnished by the increased areas over which the whole of the snow-fall does not melt each year, these increased areas being produced by the fall of the snow-line as a result of lower atmospheric temperatures. The precipitation in the Glacial period may have been rather less per square yard than it is now; but this was more than made up for by the increase in the size of the alimentation areas. Paschinger[1] is of opinion that the determining factor in the height of the snow-line is above all the temperature of the air, and as a result of the study of the precipitation and temperature of the earth he considers that, in general, both in the longitudinal direction and in the latitudinal direction the influence of warmth on the height of the snow-line is greater than that of precipitation. He shows that in the Swiss Alps the snow-line is much higher on the warm south side than it is on the colder north side.

There is one important consideration which has caused many to reject the precipitation theory as an explanation of the glaciation of Switzerland. In the Swiss valleys one can often see where the upper limit of the old ice-fields stood. Below the limit the rocks are more or less smoothed and levelled; above they are broken and craggy. If such a valley has glaciers and snow-fields at its source, it will be noticed, as one passes up the valley, that the craggy ridges are continuous with these that rise above the *névé*, and that the *névé* abuts directly against them. There are no signs in these elevated regions that the *névé* was ever thicker than it is now; and the view taken is that during the Glacial period the *névé*-covered region was greatly extended in area, but that the higher regions then presented much the same appearance they do now. Had the snow-fall in the past been much greater than it is at present, signs of thicker ice and *névé* would now be visible at the higher as well as the lower levels.

The more carefully the question of the cause of glacier advances and retreats has been studied in the field the more certain it has appeared that all considerable glacier fluctuations have been due to fall of temperature, accompanied, perhaps, by a slight decrease in the precipitation per square yard. Much more snow is converted into ice, but this has been due to the greater area over which it did not entirely melt. There is good reason to believe that in Switzerland the snow-line was so low in the Glacial period that even the great mass of ice which covered the region of Lake Geneva rose above it, and that, therefore, the whole of the Rhone Glacier trunk, and

[1] Peterman's *Mitteilungen*, i, pp. 57–60, 1911, and Pet. *Mitt. Ergangungsheft*, No. 173, Gotha, 1912.

a great portion of the piedmont it formed, were alimentation areas. The ice had to spread as far as Lyons before a sufficiently large ablation area could be formed to enable the warm air and rain of the lower regions to melt the ice completely.

Penck & Bruckner[1] express themselves to the following effect: "The Alps during the Ice Age appeared essentially different to the Greenland of to-day. They bore no inland ice. In the interior of the mountains there was no continuous *névé* field. The individual glaciers were very similar to those of the present day—widely separated from one another by *névé* ridges, which are not to be compared with the nunataks of Greenland. The ice-stream network showed, therefore, a similar slope development to the Greenland inland ice; it formed in the middle a smooth arching shield, which became steeply bent at the margin. But above this shield still rose the *névé* ridges, in the North Tyrol by about 1,000 to 1,500 metres, in Switzerland in places by about 2,000 or even 2,500 metres, and from these *névé* ridges separate glaciers sank down to the ice-stream network, usually with extreme steepness, but at times with gentle gradient. The Ice Age glaciers displayed a swelling of the tongues, but not at the same time a swelling of the *névé* fields of the present glaciers. Now if during the Ice Age the *névé* fields were no fuller than now, we cannot ascribe the glacier development during the Ice Age, compared with that of the present day, to an increase in precipitation, but must trace it to a decrease of ablation."

The question of the climatic conditions of the Ice Age will be found to have been very fully discussed by Penck & Bruckner as far as the Alps are concerned. They are decidedly of opinion that the phenomena exhibited in this area show that the Ice Age was essentially one of low temperature, not of increased precipitation. They conclude that at the culmination of the Glacial period the snow-line stood at an altitude of 1,200 metres below the present snow-line, and that the frost period at this low level was of equal duration to that which exists at the present snow-line. Such a fall of the snow-line would enormously increase the alimentation areas.

From a comparison of the Ice Age snow-line with that of the present day Penck & Bruckner also conclude that the general winds of the Ice Age blew, as regards direction, much as they do now, for, from the close relationship between the height of the snow-line during the Ice Age and the present distribution of precipitation, they hold that during the Ice Age a similar distribution of precipitation existed as at the present day; that in particular also at that time the rain-bringing wind was the west wind, and that the 'adria' bestowed on the south-east angle of the Alps abundant precipitation.

At the present time the snow limit, although of variable height on the same latitude, is higher in the Tropics than it is in the Frigid regions. But it is also often lower where the precipitation is greatest. Thus we have in the Andes a lower snow-line where the precipitation is greatest. North and south of this point the snow-line

[1] *The Alps in the Ice Age*, p. 1141 et seq.

rises, but as we go further north or south the effect of latitude begins to tell, and the snow-line falls rapidly as the Polar areas are reached. However, even in the Polar areas, the snowfall is often so small in many districts that it is all evaporated or melted by the summer sun.

A change in the direction of the winds, and, therefore, of the areas of greatest precipitation, might cause some of the present glaciers to disappear and fresh ones to appear in other places, but it could scarcely cause intense glaciation over large areas which are now free from ice. The greater prevalence of northerly winds in the Northern Hemisphere would lead to drier conditions there, and if such occurred British Columbia, Alaska, and Greenland would be less ice-covered than at present. But the Ice Age does not appear to have been either due to an alteration of any note in the direction of the winds, or to any notable increase in the precipitation.

Tutkowski has maintained that dry conditions existed at the edges of ice-sheets owing to cold winds blowing off them. That this has been the case is very likely, but here we are only dealing with local effects, the precipitation being decreased outside the margins of the ice-sheets and increased to a like extent on the ice-sheets themselves.

With regard to the greater glacier advances which brought the ice down on to the lowlands in many continental areas, W. B. Wright[1] takes the view that it is to change of temperature, and not increased precipitation, that we owe the Ice Age. Some other glacialists do not seem to be of this opinion, for quite recently it has been maintained that the minor oscillations are due to increased precipitation.

As far as can be judged from the evidence of glacial moraines, etc., it would appear that even the greater advances and retreats of the glaciers in Pleistocene time did not take place in a regular manner. The ice margins appear to have always advanced or retreated in an irregular way. The moraines formed during the retreat of the ice-sheets show this most clearly. These moraines lie one behind the other, each moraine showing where the ice rested for a time, or where a temporary advance stopped. It might be urged that the greater oscillations are due to one kind of climatic variation, whereas the smaller oscillations are due to another kind. Indeed, it would appear that in some quarters the greater variations are considered to be due to changes of temperature and the smaller ones to precipitation changes. But it is impossible to divide the glacier fluctuations into two groups, the large and the small. Glacier variations are of all magnitudes, and it appears to be more reasonable to regard all glacier fluctuations, except perhaps some of the annual or very inconsiderable ones, as being due to fall of temperature.

That neighbouring glaciers very often do not advance and retreat together is often difficult to explain. Throughout any particular region, however, where there are a large number of glaciers, the majority of them move in close agreement the one with the other.

[1] *The Quaternary Ice Age*, p. 146.

III.—Small Pit and Mound Structures developed during Sedimentation.[1]

By E. M. Kindle.

(PLATE XIII.)

Introduction.

SEDIMENTARY rocks show a variety of minor structures whose origin has been obscure. Among these are the small circular pits and mounds which sometimes mark the surfaces of sedimentary strata. Such of these as cannot be referred to rain-prints or the work of worms are apt to be referred by the geologist to some obscure type of concretion.

Since the publication of Lyell's[2] excellent description of recent and fossil rain-prints most of the small shallow pits and mound-shaped protuberances met with on the surface of stratified rocks have been ascribed to the work of raindrops. Lyell in describing rain-prints mentions also certain small protuberances resembling rain-print casts on dried ripples of mud from the Bay of Fundy, which Faraday duplicated experimentally by introducing air into the lower part of a tube of mud. These on bursting gave cavities resembling in size the ordinary rain-prints, but in nearly all cases without any rim projecting above the general surface as in rain-prints.

In the present paper it is proposed to describe processes of sedimentation observed under laboratory conditions which result in the formation of miniature pits or mounds at the top of chimney-like tubes in the falling sediment. Some of these are comparable with raindrop impressions and may have been frequently mistaken for rain-prints when met with in consolidated rocks. It is believed too that the processes observed in the experiments to be described should be given consideration as possible factors in the explanation of certain types of concretions.

The experiments on which this paper is based illustrate an important series of phenomena attendant upon sedimentation which are allied to, if not identical with, those known to chemists under the general term *catalysis*. These include changes in water, suspended sediment resulting in flocculation and deposition, which are brought about by the presence of agents which themselves remain stable and are not precipitated. In other words, the active or predisposing agent does not unite with the precipitate. Professor Brewer,[3] who was one of the first to investigate this subject, found that very fine sediment may remain in suspension for as much as six years when left undisturbed in fresh water, while the same sediment might be precipitated in a few minutes in sea-water. With some clays the precipitation is as much in thirty minutes in salt water as it is in as many days or months with fresh water. A considerable amount of

[1] Published with the permission of the Director of the Geological Survey of Canada.

[2] "On Fossil Rain Marks of the recent Triassic and Carboniferous Periods": Quart. Journ. Geol. Soc., vol. vii, pp. 238–47, figs. 1–8, 1851.

[3] Wm. H. Brewer, "On the Subsidence of Particles in Liquids": Memoirs Nat. Acad. Sci., vol. ii, pp. 163–75.

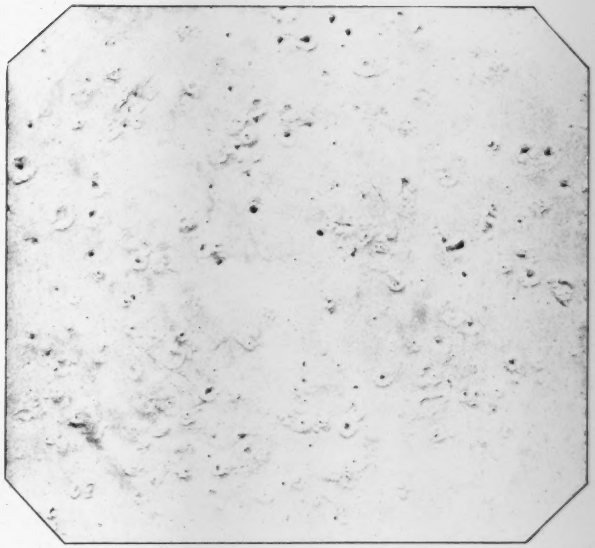


Fig. 1a.

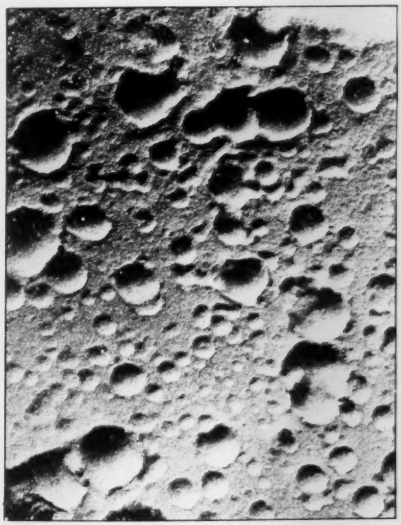


Fig. 2.

Fig. 1b.

Figs. 1a and 1b.—Pit and mound-structures developed in sedimentation.
Fig. 2.—Impressions of rain-drops from Bay of Fundy.

experimental work has been done on this subject by Reade and Holland.[1] They have tried a large variety of fine clays. From these standard turbidity preparations of water were prepared in which weight of fine clay in a given volume was known. To these were added as precipitants in their experiments: (1) sea-water, (2) calcium dicarbonate, and (3) calcium sulphate. Equal volumes of precipitant and muddy water were mixed, and time of flocculation and complete clearing noted. Flocculation was always far more rapid than in the case of untreated water. The work of these and other authors has clearly shown the effect of salt and other constituents of marine waters in accelerating sedimentation.

In the following experiments, which were made at air temperatures with the fine-grained blue Pleistocene clay of the Ottawa Valley, attention will be directed to the action of the vertical currents which are developed during the deposition of clay sediment in the presence of salt.

Experiments.

Two quarts of water were thoroughly mixed with 3 cubic inches of clay and placed in two milk bottles of quart size with flaring type of neck. Two tablespoonfuls of salt were mixed with one (A), the other (B) remaining a freshwater mixture. At the end of ten minutes the flocculated clay in A had settled 2¼ inches, and the upper 2¼ inches of the mixture was clear enough to read fine print through neck of bottle. In ten minutes the sediment had settled 4½ inches, the mixture being perfectly clear in the upper part. The freshwater mixture showed no clearing during this interval. The settling was accompanied by constant upward currents of sediment all round the sides of bottle, starting from the contact of the flared and straight-sided part of the bottle. After the top of sediment had settled to the level of the straight-sided portion of bottle these upward currents on the sides ceased, and the surface of sediment at this stage was covered over by small fumarole-shaped mounds, 3 to 10 mm. in diameter, each with an opening at the summit the size of a pin-head or smaller. The B mixture showed no sign of clearing during this period. Eighteen hours after starting this experiment 2 inches of sediment had fallen to the bottom of A, and the liquid above was perfectly clear. The sediment still had the irregular miniature-mound covered surface noted above. No settling appeared to take place in B during this time. After forty hours, settling had nearly ceased in the saline mixture, leaving perfectly clear water above the 2 inches of sediment. The freshwater bottle showed its original turbidity throughout. Another freshwater mixture of this clay remained turbid after standing 2½ months. At the end of forty hours the saline mixture was thoroughly shaken and sedimentation started over again. The phenomenon noted above was repeated as already described, except that the process was slightly more rapid than in the first case

In order to test the effect of the shape of the containing vessel on the production of the ascending currents noted above around the sides

[1] R. M. Reade & P. Holland: "Sands and Sediments," Pt. I: Proc. Liverpool Geol. Soc., vol. x, pp. 48-78, 1906.

of the vessel, another clay mixture in water was prepared, and placed in an ordinary table glass with vertical sides. The mixture was left to settle after adding a level teaspoonful of salt. After two hours the saline mixture showed at the top 1⅝ inches of perfectly clear water, while another glass with a duplicate mixture, but without salt, showed no indication of clearing. This experiment gave no indication of the ascending currents along the sides of the glass seen in the bottle, hence the strength of these currents in the bottle must be ascribed to the shape of flaring neck expanding downwards. In the glass as in the bottle, however, the chimney-like tubes opening into miniature craters and mounds were developed over the surface. But instead of being uniformly distributed over the surface as in the bottle, they were grouped around the sides of the glass and near the centre of the surface of the sediment. The largest one had a diameter of ⅜ inch. Observation of the pin-hole openings in the centre of each of these tiny structures showed ascending currents of water which could be recognized by occasional particles of sediment coming up through them. After fifteen hours the upper 2¼ inches of the glass was perfectly clear. The other glass was opaque from the top down, showing no evidence of the beginning of settling.

In order to further study the action of the upwelling currents which produce the small mounds and pits on the surface of the subsiding sediment another mixture of the clay and water to which a small quantity of salt had been added was placed in a tube, 30 × ⅝ inches. The tube affords the best possible means of observing the strong upwelling current action developed in a mass of subsiding sediment if it is set in a position inclined a few degrees from the vertical. Instead of the numerous miniature currents which would develop if left in a vertical position a single strong current then develops on the upper side of the tube, which carries upward a steady stream of the small particles of sediment. The current is apparently the resultant of the gradual downward movement of the whole subsiding mass of sediment in the upper part of the tube. This mass had subsided 14 inches in about 1½ hours. In two days it had subsided 20½ inches. On the third and fourth days subsidence amounted to only 1 inch, and then dropped to ⅛ in. per day for two or three days before becoming imperceptible. These currents belong apparently to the class of phenomena called convection currents,[1] although there is no noticeable temperature difference between the upper and lower parts of the mixtures in which they are produced. In some cases the current builds a mound-shaped mass about the mouth of the tube ; in others a circular pit with a rim about the margin develops instead of the mound. Sometimes, instead of either of these, pin-head depressions appear over the surface. Beehive-shaped protuberances with a small opening at the top are the most common. The appearance of the peculiar surface which is developed on a precipitate in which salt is the accelerating factor in throwing down the sediment is shown in Figs. 1A and B. The clay mixture shown in this Figure was placed in a vessel 6½ inches deep, which it filled and

[1] Robert B. Sasman, "Types of Prismatic Structure in Igneous Rocks" : Journ. Geol., vol. xxiv, p. 219, 1916.

photographed after settling two hours. Half of the same mixture after being shaken was placed in a vessel 10 × 6 inches, and allowed to settle in order to see how the increased lateral extent and decreased (¼ in.) depth would affect the currents in the body of the mixture and the resulting surface features. In this shallow vessel only a few small and poorly developed vents appeared.

Summary and Discussion.

The experiments which have been described show that sedimentation in salt water, when very fine sediments like mud are involved, is accompanied by the development of vertical currents. Parallel experiments with fresh water showed no evidence of this phenomenon. These upwelling currents keep open vertical tubular channels through the subsiding sediment, and develop in some cases around the mouths of their upper extremities shallow pits, somewhat resembling in outline raindrop impressions, but differing through lacking the sharply defined rims which characterize rain-prints (Fig. 1). Under certain conditions these vertical currents, instead of ending in shallow basins, build up around their upper terminals mound or chimney-like protuberances which have the appearance of small concretions or the work of burrowing invertebrates. Under natural conditions these vertical currents would probably be effective in developing surface features on the sediments only where deposition was very rapid, as in the delta area of a large river. Where the deposition of mud is going on at the rate of 12 inches in four days,[1] as has been reported on parts of the Gulf coast, the features which have been described would be very likely to be developed. It is quite possible that the structures described when developed under marine conditions would be much larger than any which can be produced under laboratory conditions. Certain curious funnel-shaped depressions which were observed by Mr. L. D Burling and myself on a mud-bar in one of the Bay of Fundy estuaries, near Truro, N.S., are believed to belong to this class of phenomena. The largest of these depressions were 12 inches wide and 4 inches deep, while the smallest were about one-fifth of this size. At the time they were examined the origin of these very regular funnel-shaped pits was a puzzle to both observers.

The vertical tubular canals which are developed under the conditions which have been described would doubtless be closed in nearly all cases by the pressure of the adjacent sediment as soon as the ascending currents ceased. The small pits or mounds which are formed about the upper ends of these channels would, however, remain at least for a time, and under favourable conditions might be preserved as permanent features on the surfaces of the strata. The courses of the vertical canals, although partially or completely closed, might remain the routes of maximum movement of waters percolating through the sediments for an indefinite period. When such waters carried with them and deposited mineral matter, vertical concretions cylindrical in section like the remarkable log-like

[1] Louisian Gulf Biological Station Bull. 3, p. 28, 1905.

concretions[1] in the Potsdam sandstone near Kingston might be developed.

[NOTE.—Fig. 2 (added by the Editor to this Plate) has been reproduced from a photograph taken direct, by the kind permission of Dr. A. Smith Woodward, the Keeper of the Geological Department of the British Museum (Natural History), Cromwell Road, London, from one of the original dried slabs of reddish mud, presented by Sir Charles Lyell from the Bay of Fundy, Nova Scotia, which are still carefully preserved in the Geological Gallery, and were described by Lyell in his paper "On Fossil Rain-marks of Recent Triassic and Carboniferous Periods", April 30, 1851 (see Quart. Journ. Geol. Soc., vol. vii, pp. 238–47. See also woodcut, p. 240), where he writes: "The finest examples sent to me from Kentville (Bay of Fundy) were made by a heavy shower which fell on July 21, 1849, when the rise and fall of the tides were at their maximum in that small estuary which opens into the Basin of Mines. The impressions [see *our* reproduction Pl. XIII, Fig. 2] consist of cup-shaped or hemispherical cavities, the largest being fully half an inch in diameter, and from one-tenth to one-sixth of an inch deep; but there are very few of such dimensions. The depth is chiefly below the general plane of stratification, but the walls of the cavity consist partly of a prominent rim of sandy mud, formed of the matter which has been forcibly expelled from the pit, and this margin or lip sometimes projects as much above the plane of the stratum as the bottom of the pit extends below it. The rim of the largest rain-prints is sometimes no less than one-twelfth of an inch broad, but it is usually much narrower. The outer side of it is often perpendicular or almost overhanging. . . . All the cavities having an elliptical form are deeper at one end, where they have also a higher rim, and all the deep ends have the same direction showing towards which quarter the wind was blowing. Two or more drops are sometimes seen to have interfered with each other, in which case it is usually possible to determine which drop fell last, its rim being unbroken. . . . " Lyell adds a note to his paper: "Since the above was in type, my attention has been called to a notice by Dr. Buckland[2] 'On Cavities caused by Air Bubbles on the Surface of Soft Clay', which he justly observed 'must be carefully distinguished from impressions made by rain' ".

As bearing upon the present paper, we may draw attention to a Plate (Pl. IV, Vol. II, GEOL. MAG., 1865, p. 137), reproduction of markings on the surface of a slab of Carboniferous Sandstone from Bishop Auckland, described by Mr. J. Duff. Also suggested explanation by Mr. Alexander Bryson, accompanied by a text-diagram figure (GEOL. MAG., 1865, pp. 188–91), in which the writer shows that these horseshoe-like markings are in all probability to be attributed to the heaping up of grains of sand against the windward side of the burrows of the common sandhopper (*Talitrus saltator*), the

[1] N.Y. State Mus. Bull. 145, pl. xiii.
[2] Reports of British Association, 1842, Trans. Sect., p. 57.

moisture of the burrow causing the grains to adhere and dry in a crescent-shaped form around the margins. After the surface-markings have dried and slightly hardened, dry dust or sand must blow over them before a fresh tidal deposit flows over and entombs them to form a problem for some future geologist to puzzle over.—Ed. Geol. Mag.]

EXPLANATION OF PLATE XIII.

Fig. 1*a*.—Circular impressions developed on the surface of water-laid sediment by vertical currents.

,, 1*b*.—Part of the same surface seen in Fig. 1*a*, rather more enlarged.

,, 2.—Photograph of part of a slab from the Bay of Fundy (see *supra*, p. 546).

IV.—A Sketch of the Structure of the Northern Pennines.[1]

By Dr. A. Wilmore, F.G.S.

THIS paper attempts a brief summary of the structure of the Northern Pennines for geologists and geographers, especially for those who are interested in the relation of geographical form to geological structure. It is, for the most part, a re-statement, and advances little that is new; but it is thought that the present visit of the Association to the North may be a fitting opportunity to summarize our knowledge of the structure of an interesting region, especially as considerable progress has been made in our detailed knowledge of the Northern Pennines since the visit of the Association to Newcastle in 1889.

By the "Northern Pennines" as treated in this paper, we mean that well-defined part between the two great gaps—the Tyne Gap and the Craven or Aire Gap. In this part of the Pennines the mountain masses are broader and higher, and the structure is somewhat different from that of the Pennines south of the Craven Gap. The familiar anticline is not so conspicuously developed as in the southern half of the Pennines.

In the Northern Pennines the student may see very clearly indeed the broad dependence of the topography upon rock-character, rock-position, and geological history.

The Craven or Aire Gap may be taken as a convenient starting-point. This is a lowland region of roughly triangular form drained by four local river systems: the Wharfe, the Aire with Broughton Beck, the Ribble with the Lancashire Calder, and the Wenning (one of the feeders of the Lune). Each of these outlets of the 'gap' is utilized by a railway. The Leeds and Liverpool Canal follows the valleys of the Lancashire Calder and the Aire, and crosses the Pennines at an elevation of a little over 500 feet (the highest point is at Foulbridge Tunnel, near Colne).

The Middle Pennine Gap is determined by the great Craven Fault system and the folding of the strata to the south and south-west of the fault. The general direction of the folding is from W.S.W. to

[1] Read before the British Association, Section C (Geology), Newcastle, 1916.

E.N.E. Near the Fault there is considerable and somewhat intense local folding, and probably some repetition of the beds.

North of the Craven Gap, and stretching to the Tyne Gap, is the Plateau, or Block country—the Northern Pennines of this paper—determined mainly by the three great western fault systems; these are the Pennine, the Dent, and the Craven Faults. Three 'blocks' of the Northern Pennines are thus formed: (1) the Cross Fell block, (2) the Mallerstang or Dent block, (3) the Ingleborough-Penygent block. On these plateau blocks the mountains stand, excellent examples of mountains of circumdenudation or residual mountains. Ingleborough or Penygent may be taken as a type of these mountain masses, standing on the plateau floor of the Great Scar Limestone and capped by outliers of Millstone Grit. The Great Scar Limestone is gradually replaced towards the north by the coming in of the Bernician type. The Great Scar Limestone of the Penygent block is a region famous for pot-holes and underground streams, such pot-holes as Gaping Ghyll and Alum Pot being well known. On the great plateau numerous streams disappear to reissue in the valleys below, frequently at the unconformity where the limestone, with or without its basement conglomerate, lies almost horizontally on the upturned edges of the Older Palæozoic rocks.

These plateau blocks are not all similarly related to the adjacent westerly regions. On the east of the great Pennine Fault is the wedge-shaped Vale of Eden, filled with Permian and Triassic strata. There is an interesting inlier chiefly of Older Palæozoic rocks occurring between the Carboniferous plateau block and the New Red beds of the plain. This is known as the Cross Fell inlier, and is characterized by a series of magnificent 'pikes', like a narrow strip of the Lake Country tacked on to the western edge of the Pennines. This inlier stretches from near Brough in the south to Melmerby in the north. The *Dent Fault* has its downthrow to the east, and along the complex fault-line the Carboniferous Limestone is in contact with the Older Palæozoic rocks of the Howgill Fells and the moors to the north and north-east of Kirkby Lonsdale. The Carboniferous block to the east of this fault is the Mallerstang block of this paper. It is remarkable for the great number of mountain masses which rise to between 2,000 and 2,400 feet. An eastern part of this block is the original region of the Yoredale of Professor Phillips (Wensleydale is Yoredale or Uredale). The Craven Fault system throws the Carboniferous Limestone, chiefly the Great Scar Limestone, against Permian, or Coal-measures, or Millstone Grit, or the higher divisions of the Carboniferous Limestone itself.

To the geographer the change of scenery in crossing these faults is most interesting. The view from the western limestone scars of the Cross Fell block across the Vale of Eden to the Lake District mountains is one of the finest in Britain. The change from the Older Palæozoic Howgill Fells, Grayrigg Fells, Middleton and Barbon Fells eastward across Garsdale or Dentdale to the Carboniferous Fells of the Yoredale country of Mallerstang is, perhaps, not so striking but is yet very marked. The change from the Penygent block—with its great plateau floor, its step-like Yoredale mountains, capped with grits,

and its steep-sided gorges—to the rolling country of Bowland and the Craven Lowlands provides one of the best geographical contrasts in the North of England.

To the geologist there are many interesting problems, in which considerable progress has been made in the last quarter of a century, but many points in which are still obscure. Some of these are: the change in the type of stratification from the Pendleside type and Bowland type at the southern end of the region through the Yoredale type to the Bernician of the north, and the satisfactory correlation of the different facies; the relation of the now famous 'knoll' limestones, best seen immediately south of the Craven Fault, to the Lower and Upper Carboniferous Limestones of more normal type, and the whole problem of knoll-structure; the sharp folding immediately in front of the faults. Dr. Marr has pointed out the knoll-like structure produced in the Keisley Limestone of the Cross Fell inlier, and has compared it with the limestone of Draughton Quarry to the south of the Craven Fault. There are many folded greyish-white limestones in the knolls of Craven which are very much like those of Keisley; the Carboniferous Limestone floor and the different times of its submergence, on which new light has been thrown by Professor Garwood's recent work. An interesting paper on this subject was presented by Dr. Vaughan last year—his last paper; the relation of the pre-Pennines—a part of the old Caledonian system, the rocks of which seem to have had cleavage developed in them during the early Devonian folding, and which suffered denudation in later Devonian and early Carboniferous times; the immense thickening of the Millstone Grit to the south, and the precise relation of its rock-material to the denudation of the Caledonian Alps; and the age of the various foldings and faultings which have determined (in the main) the present Pennines.

All these problems have their geographical aspect. The old Palæozoic floor in Ribblesdale and the bit of wild scenery of another type—an inlier in the Carboniferous of the Penygent plateau; the striking rounded and ovoid form of the Craven knolls; the apparently great thickness of grit of the Bowland Fells, and especially of the Pendle Range—these and many similar phenomena interest alike the geologist and the student of physical geography.

The age of the faults and folds has been discussed by several distinguished workers. There was, of course, the pre-Pennine folding in Devonian times; faulting was possibly in progress in Carboniferous times as taught by Mr. Tiddeman; great earth-movements occurred at the end of the Carboniferous period; Professor Kendall has shown that there was upward movement of the Pennines in early Permian times, between the deposition of the Lower Brockram and the Upper Brockram; the great faults, especially the Pennine and Craven Faults, and the earlier folding were probably Permo-Triassic and possibly in part post-Triassic (the Craven Fault is, in the main, later than the Dent Fault, as it cuts the latter sharply at the southern end near Kirkby Lonsdale); the great continent- and mountain-building movements of mid-Tertiary time probably gave (according to Dr. Marr) the final broad form to the

Northern Pennines, and determined the *general* consequent drainage system of the region.

Dr. Marr, Professor Kendall, Professor Fearnsides, and others have dealt with some of the interesting and important Glacial and post-Glacial changes of drainage, of which there are many examples in the Northern Pennines. These Pleistocene changes may be studied especially well in the Howgill Fells, the Bowland Fells, and the Craven Lowland country.

NOTICES OF MEMOIRS.

I.—Address to the Geological Section of the British Association for the Advancement of Science, Newcastle-on-Tyne, 1916.[1] By Professor W. S. Boulton, D.Sc., F.G.S., President of the Section.

WE are assembled here in Newcastle-on-Tyne, the heart of a great industrial community, where coal, the very lifeblood of industry, has been raised for more than three centuries in ever-increasing amount; and of all minerals which our science has helped us to win from the earth for man's comfort and use, coal must assuredly take pride of place. . . .

It has been the custom for the President of this Section to deal with some large, outstanding question of theoretic interest, and on this occasion I wish to refer to the present outlook of Economic Geology, more especially in this country.

If we attempt to compare the growth of applied geology in Britain with that, say, in the United States of America, or even in our great self-governing Dominions, or to appraise the knowledge of, and respect for, the facts and principles of geology as directly applicable to industry in these countries and in our own, or to compare the respective literatures on the subject, I think we shall have to confess that we have lagged far behind the position we ought by right of tradition and opportunities now to occupy. The vast natural resources of the countries I have named have doubtless stimulated a corresponding effort in their profitable development. But making due allowance for the fact that Britain is industrially mature as compared with these youthful communities, we cannot doubt that in this special branch of geology, however splendid our advances in others, we have been outstripped by our kinsmen abroad.

This comparative failure to apply effectively the resources of geology to practical affairs is unquestionably due, in no small measure, to our ignorance and neglect of, and consequent indifference to, science in general, more especially on the part of our governing classes. This War, with all its material waste and mental anguish, may bring at least some compensation if it finally rouses us from complacence and teaches us to utilize more fully the highly trained and specialized intelligence of the nation.

[1] Slightly abridged.

The Geological Survey.

In any discussion of the present outlook of economic geology in Britain we naturally turn first to the work of the Geological Survey. When in 1835 the National Survey was founded with De la Beche as its first Director, it was clearly realized by the promoters that its great function was to develop the mineral resources of the Kingdom, which involved the systematic mapping of the rocks, and the collection, classification, and study of the minerals, rocks, and fossils illustrative of British Geology. For upwards of eighty years this work, launched by the enthusiasm and far-sighted genius of De la Beche, has been nobly sustained. We geologists outside the Survey are ever willing to testify to the excellence, within the Treasury-prescribed limits, of the published maps and memoirs. Indeed, it would be difficult to name a Government service in which the officers as a body are more efficient or more enthusiastic in their work. . . .

But the time is opportune, I think, when we may ask whether the Survey is fulfilling all the functions that should be expected of it; whether it is adequately supported and financed by the Government; whether it should not be encouraged to develop along lines which, hitherto, from sheer poverty of official support, have been found impracticable.

It will be admitted that the re-mapping of the coalfields, which were originally surveyed on the old 1 in. Ordnance Maps more than half a century ago, before much of the mining information now available could be utilized, is a primary duty and a pressing public necessity. But it would be a great mistake to allow other areas which have apparently little or no mineral wealth, and are destitute, so far as we at present know, of any geological problem of outstanding interest, like the problem of the Highland Schists, to remain, as at present, practically unsurveyed. Take, for example, the great spread of Old Red Sandstone in South Wales and the Border counties of England, which on the present Government maps is indicated with a single wash of colour, and here and there an outcrop of cornstone. It is true that the southern fringe of this area has been recently surveyed in more detail in re-mapping the South Wales Coalfield; but there remain upwards of 2,000 square miles of Old Red Sandstone unsurveyed. A map indicating merely the outcrop of the main bands of sandstone, conglomerate, marl, and limestone would be of great assistance to engineers in such works as water-supply and sewage, as well as to agriculture. I am aware that many other areas more clamorously demanding a survey could be cited; but I give this example because it happens that a few months ago the Survey maps of the area were found to be useless for the purposes of an engineering work which had necessarily to be based upon the local geology.

It is sometimes said, and with truth, that the great function of a Survey is to produce a geological map which should be a 'graphic inventory', so far as its scale permits, of the mineral resources, actual and potential, of a country. After all, such a map, even when accompanied with its horizontal section and used by the trained geologist, is a very imperfect instrument by which to summarize and

accurately to interpret the results of the surveyor's work. There is so much to express that a single map will not always suffice. It may be desirable to show not only the outcrops of the strata at the present surface, but the thickness of the beds, and even the shape of a buried landscape or sea-planed surface, now unconformably overlaid by newer rocks. That the Geological Survey are alive to the importance of such work is shown by some of their recent publications. The memoir on the *Thicknesses of Strata in the Counties of England and Wales, exclusive of rocks older than the Permian*, published this year, is a most valuable compilation, bringing together officially for the first time a vast amount of useful fact, mainly from open sections and borings. May we not look forward to the time when the Survey can issue maps with 'isodiametric lines' showing the thicknesses in the case of important beds; for example, sheets of productive coal-measures, water-bearing beds, and so forth? In any case, we may confidently expect maps that will show by contours the shape and depth of those buried rock-surfaces, whether unconformities or otherwise, which limit strata of peculiar economic value. The Director of the Survey has already given us a foretaste in his valuable and suggestive maps of the Palæozoic platform of South-East England,[1] and in the contoured maps of the base of the Keuper and of the Permian to the east of the Yorkshire, Nottingham, and Derby Coalfield, and the rock-surface below sea-level in Lincolnshire.[2]

Some of the new edition 1 in. colour-printed maps, excellent though they are, suffer by being overburdened with detail already, and we ought to consider whether it is not possible to issue maps of selected districts in series, as is done in the beautifully printed atlases of the United States Geological Survey, where each map of the series shows one particular set of features. . . .

We have yet to realize that technical knowledge, of the highest value to the country and obtained at great cost and labour, should be distributed as widely as possible, and at the lowest or even at a nominal charge. I would go further, and put much of the technical information in a simple and attractive form. We might even hope, for example, to eradicate the lingering superstition of the water divining-rod, which is still requisitioned by some public bodies. How admirably clear, simple, and direct is the information on water-supply in the little Survey memoir entitled *Notes on Sources of Temporary Water Supply in the South of England and Neighbouring Part of the Continent*, price 2*d.*, evidently produced under the stress of War conditions, and all the better for it.

During the last few months a series of much more important publications by the Geological Survey has appeared. I refer to the Special Reports on the Mineral Resources of Great Britain, of which some six volumes are completed. The Survey is to be congratulated upon starting a line of investigation and report which is a return to some of its oldest and best traditions. The Preface, by the Director, to the first volume of the series, that on the *Tungsten and Manganese Ores*, is illuminating and symptomatic, for it reveals a consciousness

[1] A. Strahan, Pres. Address to Geol. Soc., 1913.
[2] Mem. Geol. Surv., *Thicknesses of Strata*, pp. 88 and 110.

of our shortcomings in the past and points the way to reform in the future.

He says: "The effects of the War, in increasing the demand for certain minerals of economic value, have led to many inquiries as to the resources in Britain of some materials for the supply of which dependence has been placed upon imports, and have raised the question whether further exploitation and improvements in method of preparation of those minerals would now be justified."

Valuable mineral deposits in old workings, the delimitation of still unworked ground, old waste-products now of great value under changed conditions of demand, are vital matters dealt with in these volumes. In a pregnant passage the Director says: "It has become apparent also that some of our home products would be at least equal to material we have been importing, provided that they could receive equally careful preparation for the market, and that with improved treatment and greater facilities for transport, they would be fit to compete with some of the foreign materials."

In the volume on *Barytes and Witherite*, it is stated that "apart from the very highest qualities, there is no scarcity of barytes in Great Britain, but that notwithstanding that fact more than half the amount used in this country has been imported, and that 34 per cent of the amount used came from Germany". Owing to fineness of grinding and low freights, the imports of this mineral from Germany have increased at a bigger rate than our own output, a state of things that surely will never recur. . . .

The Geological Survey and the Imperial Institute.

I desire here to refer to the Research Department of the Imperial Institute at South Kensington. From the Scientific and Technical Research Department reports and papers appear from time to time on the mineral resources of Britain and the Colonies. Thus, "The Occurrence and Utilization of Tungsten Ores" appeared in 1909, and similar reports on the ores of chromium, titanium, zinc, etc., and on the coal and iron resources of the British Crown Colonies and Protectorates have been published. These reports are all unsigned, although presumably written by competent persons. Such investigations, although primarily dealing with the Colonies, necessarily overlap to some extent similar work undertaken by the Geological Survey in this country. The point, however, I wish to make is that the work, both for Britain and the Crown Colonies and Protectorates in so far as it relates to prospecting, mapping, and reporting on mineral resources, could be done more effectively by the staff of the Geological Survey. There is no need to duplicate such a staff in the Government service. Men of the standing of our Government surveyors, specially trained on the economic side, who are at present investigating our home mineral resources, are admirably fitted to do similar work in the Crown Colonies. As for the self-governing Dominions and India, they have their own Geological Surveys and may be relied upon to develop their own mineral wealth. . . .

So far as I am aware, there is not any official connexion between the Imperial Institute and the Geological Survey; and it is to be regretted that in the recent Act of Parliament whereby the management of the Institute is definitely transferred to the Colonial Office, and which provides for the appointment of an Executive Council of twenty-two members to supersede the present Advisory Committee, no provision is made for the co-operation of the Geological Survey in the geological and mineralogical side of the Institute's work. And may I say, in passing, that I think it is also a grievous mistake to develop a Research Department at the Institute without making some attempt to collaborate with the neighbouring Imperial College of Science and Technology, which, with its fine equipment and expert staff of researchers and teachers, should constitute a real Imperial College of Science and Research, in fact as in name?

But, these matters apart, it will be recognized on all hands that an ample field remains open for the energy and enterprise of the Imperial Institute as a Clearing House of scientific and technological knowledge for the whole Empire, and especially for bringing the results of scientific investigation into touch with the main streams of industry and commerce. . . .

The Development of Concealed Coalfields.

I pass on to consider what is, or should be, another phase of the work of our National Survey, namely, the discovery and development of concealed coalfields.

The Royal Coal Commissions of 1866 and 1901, and frequent addresses and reports by leading geologists in recent years upon the extension of our coalfields under newer rocks, bear witness to the sovereign importance of this branch of economic geology. One after the other the coalfields are being re-mapped by the Geological Survey, and we confidently expect the work to continue. But as the known coalfields become opened up and gradually exhausted, the question of the survey and development of concealed coalfields becomes ever more pressing and vital to our position as a great industrial nation.

In the Yorkshire, Nottingham, and Derby Coalfield the rapid extension of workings eastward under the Permian and Triassic cover during recent years has been remarkable; and although the estimates of its buried Coal-measures adopted by the Commission of 1901, at that time thought conservative, have since come to be regarded as too liberal, we may still rely upon a buried field of workable coals larger in area than the exposed Coal-measure ground of this great coalfield, so that the whole combined field will prove the richest in our islands.

The Kent Coalfield has made a peculiar appeal to popular imagination, partly because of its proximity to London, and its distance, amid England's fairest garden, from the great and grimy industrial areas of the North. A recent address by Dr. Strahan vividly describes the rapid exploitation of this field.[1]

[1] "The Search for New Coalfields in England": Royal Institution of Great Britain, March 17, 1916.

A problem of perhaps wider geological interest than that of the Kent Coalfield, and certainly of greater complexity, and containing the possibility of an even richer economic harvest, is the occurrence of buried Coal-measures under the great sheet of red rocks between the Midland coalfields, and under newer beds in the area to the south and east of them, towards London.

For the ultimate solution of this problem an appeal will have to be made to many geological principles of which the high theoretical interest is universally acknowledged, although their practical importance is not so immediately apparent. Thus the minute zonal work in the Chalk, the laborious studies among Jurassic Ammonites, as well as the detailed investigations of minor transgressions and nonsequences in the Mesozoic rocks generally, will all have their value when estimating the nature and thickness of cover over the buried Coal-measures. . . .

One obvious line of attack is the more intensive study of the structure of the exposed coalfields, which is made possible by our ever-widening knowledge obtained largely from coal workings, present and past. . . .

Geological Features of the Visible Coalfields which bear upon the Distribution and Structure of Concealed Coalfields in the South Midlands of England.

In touching upon this question of possible buried coalfields in the South Midlands of England, I wish briefly to refer to a few points connected with our detailed knowledge of already explored coalfields which must be taken into account. They may be grouped under two heads—

(1) The stratigraphical breaks which are said to exist within the Coal-measures themselves; and

(2) The post-Carboniferous and pre-Permian folding, and its relation to pre-Coal-measure movements.

Geologists who have made a close study of the detailed sequence of any British coalfield are fairly agreed that, while sedimentation was accompanied by a general subsidence, the downward movement was discontinuous, possibly oscillatory, as evidenced, on the one hand, by the occurrence of marine bands in a general estuarine series, and, on the other hand, by those coal-seams, particularly, which consist of terrestrial accumulations of plant-material. But on a critical analysis of prevalent views we meet with considerable difference of opinion as to the inferences to be drawn from the known facts.

Jukes-Browne, referring to Coal-measure time, says "that it was a period of internal quiescence, a period in which terrestrial disturbances were at a minimum",[1] and this notwithstanding his advocacy of the tremendous plication of the Malvern and Abberley Hills in the middle of the Coal-measure period, that is, in the interval between the Middle and Upper Coal-measures of England. Another high authority says "The Coal-measure Period as a whole was one of crust movement".[2]

[1] *The Building of the British Isles*, p. 169, 1911.
[2] Q.J.G.S., vol. lvii, p. 94, 1901.

Dr. Gibson, after a detailed survey of the North Staffordshire Coalfield, where the Middle and Upper Coal-measures are fully and typically developed, asserts that "no break has been detected in the Coal-measure sequence"; [1] and a like conclusion is to be drawn from the work of the Government surveyors and from borings in the Yorkshire, Derby, and Nottingham Coalfield and that of East Warwickshire.

Mr. Henry Kay [2] would fix a local unconformity at the base of the Halesowen Sandstone of South Staffordshire, and another at the base of the Keele Beds (or so-called Lower Permian Marls); while in the Coalbrookdale Coalfield the well-known Symon Fault, described by Marcus Scott as a great erosion-channel in the Middle or Productive-measures, subsequently filled up by the unproductive Upper Coal-measures,[3] was interpreted by W. J. Clarke in 1901 [4] as a pronounced unconformity, a view which has been generally accepted ever since, and which was eagerly seized upon by those who hold that the Malvernian disturbance occurred at this time. . . .

The plate which illustrates Marcus Scott's paper on the Symon Fault [5] shows the upper beds plotted out from the lowest workable seam in the older measures, which he assumes to be horizontal (their original position); while Clarke, using Scott's data, plots his sections from the base of the Upper-measures, which he uses as a horizontal datum-line.[6] Incidentally I may remark that in both cases the sections are drawn with a much-exaggerated vertical scale, and, of course, correspondingly exaggerated dips.

In my opinion, both these interpretations are misleading (apart from the question of scale), because in neither case is the adoption of the horizotal datum-line strictly justified by the facts. In the one case the curvature of the basin is made too great, and in the other the dips in the Middle-measures are unduly increased; for, as mining plans show, the base of the Upper-measures is by no means horizontal. The fact is that the undulations in the measures throughout the coalfield are extremely slight, there being scarcely any perceptible dip in the strata, as noted by Scott, except near what is called the "Limestone Fault", where the dips, as will presently appear, can be otherwise accounted for. Furthermore, there is a significant absence of faults other than those which affect Middle and Upper-measures equally.

I believe there is another and a simpler explanation of this classic disturbance, and one which harmonizes, in part, the views of both Scott and Clarke; and at the same time helps to give us a reasonable interpretation of the apparently conflicting statements which have been made by working geologists respecting the relationship of the Coal-measure divisions in the Midlands.

The Keuper Marls of the Midlands occur either in horizontal or

[1] Q.J.G.S., vol. lvii, p. 264, 1901.
[2] Q.J.G.S., vol. lxix, pp. 433–53, 1913.
[3] Q.J.G.S., vol. xvii, pp. 457–67, 1861.
[4] Q.J.G.S., vol. lvii, pp. 86–95, 1901.
[5] Ibid.
[6] Ibid.

very gently undulating sheets, but Dr. Bosworth has shown that around Charnwood Forest they dip in all directions, "sometimes to the extent of 20 or even 30 degrees," and that everywhere the inclination is in the direction of the rock-slope beneath, though always at a smaller angle than the slope. This local dip (or 'tip', as he calls it) "seems most likely to have been largely caused by contraction of the marls under pressure and by loss of moisture".[1]

In a paper dealing with the Coal-measures of the Sheffield district published this year,[2] Professor Fearnsides directs attention to a research by Sorby, embodied in a memorable contribution to the Geological Society of London in 1908[3] upon the contraction of clay sediment due to loss of water. It appears to me that the penetrating genius of Sorby, with that clarity of vision which comes from patient and exact quantitative experiment, may help us to clear up some of the difficulties to which I have referred. If the Coal-measure clays have lost something like five-sixths of the original thickness they possessed as mud or slime, as Sorby's quantitative experiments seem to indicate, is it not possible that the discordance we are discussing between the Middle and Upper Coal-measures is due, in part at all events, to differential contraction and consequent local sagging during the extremely slow squeezing out of the water by the pressure of overlying sediment? We must remember that the Middle Coal-measures consist essentially of clays, and that over a large part of the Midlands they were deposited on a very uneven floor, and that to start with they were therefore of very variable thickness. It is easy to see, also, that an arenaceous fringe of sediment where the measures abut against a rise in the floor would suffer far less vertical contraction from this cause than the clay, because of the very diminished "surface energy" of the constituent sand particles, and that this would have the effect of accentuating the dip due to the sag.

It is to be noted that Scott's observations and the bulk of his section referred to the central parts of the coalfield, while Clarke deals primarily with the district just north of Madeley and along the south-eastern fringe of the "Limestone Fault", which may prove to be, in my opinion, in its early stage at all events, a pre-Coal-measure ridge of limestone.

It is quite possible, indeed probable, that portions of the undulating surface of the Middle Coal-measures suffered local erosion, which, however, need not imply folding of the beds with prolonged subaerial denudation; for it seems likely that such local erosion was sub-aqueous, producing a non-sequence similar in character (and origin perhaps) to the relatively small stratigraphical breaks which have been recognized recently in the Jurassic strata in the West of England and elsewhere.

Thus, in North Staffordshire, where the Midland Coal Basin is deepest, no break between the Upper and Middle-measures exists; but approaching the southern margin of the basin, to the south of

[1] *The Keuper Marls around Charnwood*, pp. 47–50, 1904–11.
[2] Trans. Inst. Min. Eng., vol. l, pt. iii, 1916.
[3] Q.J.G.S., vol. lxiv, pp. 171 et seq., 1908.

the South Staffordshire Coalfield, where the Middle Coal-measures are rapidly thinning, there are, if Mr. Kay's observations are correct, signs of a non-sequence or local unconformity. The same is true, but on a larger scale, in the Symon Fault of the Coalbrookdale Coalfield,[1] and is to be explained, if the above reasons are valid, by the rapid variation in thickness of the Middle-measures, due to the irregular floor upon which they rest, to the consequent sagging of the beds, and also to local subaqueous erosion. Further, such partial unconformities or non-sequences would generally indicate the proximity of that marginal fringe where the Upper-measures overlap the Middle and rest on pre-Coal-measure strata.

The Middle and Upper Coal-measures of the Midlands record general but intermittent subsidence, with a considerable pause at the end of Middle Coal-measure time, followed by a much more general depression, as shown by the extended and overlapping sheet of Upper Coal-measures. But there is no evidence which I regard as convincing that regional elevation or great orogenic movements occurred until after the Upper Coal-measures were laid down.

The floor upon which the Middle Coal-measures were deposited along the southern fringe of the Midland Coalfields was a sinking and already folded and denuded floor, and it is to be expected, therefore, that these measures rest in submerged gulfs and estuaries, which would mean that some, at any rate, of the several coal basins were originally isolated wholly or in part, and their separation is not to be interpreted as due to folding and subsequent denudation.

Dr. Newell Arber has argued that the Middle Coal-measures of Coalbrookdale, the Forest of Wyre, and the Clee Hills, were deposited in three separate basins, which as regards the Sweet Coal or Productive-measures were never continuous.[2] On the other hand, just as it is certain that the Productive-measures on either side of the South Pennines were originally continuous, so it is probable that as we go northward from this southern fringe the Productive-measures spread out into more extensive sheets. . . .

As an example of such intensive geological work, I should like to refer to the detailed plotting by Mr. Wickham King of the Thick Coal of South Staffordshire on the 6 in. maps. For more than twenty years he has been engaged in collecting and tabulating an immense number of levels and other data from colliery officials, and from old and sometimes half-forgotten borings; and he has now produced a contoured map and a model to the same scale, showing in great detail the folds and faults in the Thick Coal. In 1894 Professor Lapworth, to whose initiative this work was due, emphasized the value of such "plexographic maps" of coal seams, and predicted that such maps would be drawn in all the coalfields.[3] The data obtained in South Staffordshire also enable us to determine, at

[1] Mr. Wedd has recently described a similar break between the Middle and Upper Coal-measures of the northern part of the Flint Coalfield. (See Summary of Progress of Geol. Surv. for 1912, pp. 14, 15.)

[2] Phil. Trans. Roy. Soc. London, Series B, vol. cciv, pp. 431–7: "On the Fossil Floras of the Wyre Forest, etc."

[3] Fed. Inst. Min. Eng., vol. viii, p. 357, 1894–5.

some places exactly, at others approximately, the shape of the pre-Coal-measure floor and the outcrops of its constituent formations; and to disentangle, in part, the pre- and post-Coal-measure movements. Thus we get additional evidence to show that before Middle Coal-measure time, denuded folds, with a north-west or Charnian trend, and other folds with a north-east or Caledonian trend prevailed. The post-Carboniferous and pre-Permian movements emphasized and enlarged some of these folds. As already remarked, a matter of great practical importance is as to how far these pre-Coal-measure folds interfered with the continuity of deposition of the productive series, with, for example, the original extension of the Thick Coal of South Staffordshire. Since Jukes-Browne's time it has been known that the Thick Coal group as a whole thins, and the coal itself deteriorates, southward towards the Clent and Lickey Hills. It is the discontinuity and local deterioration in an *east* and *west* direction, beyond the Boundary Faults, due to pre-Coal-measure flexures, and irrespective of post-Carboniferous movement, that I have been emphasizing.

The powerful disturbances of post-Carboniferous and pre-Permian age, which have affected all our coalfields, I have no intention of discussing here. Professor Stainier, the Belgian geologist, has just published a lengthy and able discussion on the subject,[1] while the lucid account by Dr. Strahan in his Presidential Address in 1904 and his recently summarized views in a lecture to the Royal Institution will be in the minds of all geologists.

I do not think, however, that it is generally realized what a great part the two dominant pre-Carboniferous systems of folding played in determining the trend of the post-Carboniferous flexures. In the South Pennines, in the Apedale disturbance of North Staffordshire and in the Malverns we have nearly north and south folds due to a great easterly thrust; but elsewhere in the Midlands and the North the movements were taken up, to the west of these north and south lines by the Caledonian folds, and to the east by the Charnian flexures. It is very instructive to watch in the centre of the South Staffordshire Coalfield the old Charnian fold of Silurian rocks that make up Dudley Castle Hill, the Wren's Nest, and Sedgley Hill struggling, as it were, against the newer post-Carboniferous easterly squeeze, which has impressed a north and south strike upon each of the domes, arranging them *en échelon* from north-west to south-east, and incidentally permitting the great laccolitic intrusion of Rowley Regis.

It will be found, however, that the vast majority of the folds and faults in the Midland and Northern Coalfields are not along what may be called strict Hercynian lines—that is, north to south and east to west—but along the locally older Caledonian and Charnian directions. It was as if the great north and south flexures of the Southern Pennines and Malverns, and the east and west Armorican folds of the South of England, to a large extent exhausted the mighty attack of the Hercynian movements coming from the South and East of Europe;

[1] Trans. Inst. Min. Eng., vol. li, pt. i, pp. 99–153, 1916.

while smaller intervening and relatively sheltered areas were allowed to yield along their old north-west and north-east lines.

Need for Systematic Survey by Deep Borings.

After all, when we turn our attention to the possible extension of the Coal-measures under the newer strata of South-Central England, the geological data at our disposal are lamentably and surprisingly few. Notwithstanding our eagerness to unravel the difficulties, and so to open up new fields for mining activity, very little positive progress has been made in the last twenty years. Of late a few deep borings have been sunk; one near High Wycombe, after piercing the Mesozoic cover, ended in Ludlow rocks; another at Batsford, in Gloucestershire, fifteen miles north of the well-known Burford boring, struck what are regarded as Upper Coal-measures, also resting on Silurian rocks.

At the present time it seems specially fitting to call attention once again to our haphazard method of grappling with this great economic question. Are we to go on indefinitely pursuing what is almost 'wild-cat' boring, to use the petroleum miner's expressive slang? Or shall we boldly face the fact that systematic exploration is demanded; and that this pioneer work is a national obligation, the expense of which should be a national charge?

At the meeting of the Organizing Committee of Section C, already referred to, a recommendation was forwarded to the Council in the following terms:—

"The Council of the British Association for the Advancement of Science recommends that the site, depth, and diameter of every borehole in the British Isles, exceeding 500 feet in depth, be compulsorily notified and registered in a Government Office. That all such boreholes be open to Government inspection during their progress. That copies of the journals and other information relating to the strata penetrated by the boring be filed in a Government Office under the same restrictions as those relating to plans of abandoned mines."

I would go further and urge that the Government should undertake the sinking of deep borings at selected points. This is no new idea. In his Presidential Address to the Geological Society of London in 1912 Professor Watts pleaded most forcibly the vital importance of a State-aided underground survey of the area to which I have referred. The work is too vast for individual effort, or even for a private company to undertake. It is not suggested that deep borings should be sunk with the express purpose of finding coal. What is wanted is a systematic survey by borings at such spots as are likely to throw light upon the structural framework of the Palæozoic floor and the thickness of its cover. . . .

For many years I lived near our great exporting centres of the finest steam coal in the world; and as I watched the steady and incessant streams of coal-wagons, year in, year out, coming down from the hills, I was constantly reminded that we are rapidly draining the country of its industrial life-blood. Is it an extravagant demand to ask that an infinitesimal fraction of this irreplaceable Nature-made

wealth should be set aside to provide the means for the discovery and development in our Islands of new mineral fields?

Chemical and Microscopical Investigation of Coal-seams.

The recovery of bye-products in the coking of coal, which up to the beginning of the War was almost exclusively undertaken by the Germans, is likely in the future to become an important British industry. This will ultimately demand a thorough knowledge of the microscopic and chemical structure of all the important coking seams in our coalfields.

Remembering how varied both in microscopical structure and chemical composition the individual laminæ of many of the thick coal-seams are, it will readily appear how important such a detailed investigation may become, having regard to the great variety of these bye-products and their industrial application. Moreover, thin seams, hitherto discarded, may pay to be worked, as may also an enormous amount of small coal, estimated at from 10 to 20 per cent of the total output, which up to the present has been wasted.

Geology of Petroleum.

It has been frequently remarked that in order to account for the vast accumulation of coal in the Carboniferous strata, it is necessary to postulate a special coincidence over great areas of the Northern Hemisphere of favourable conditions of plant growth, climate, sedimentation, and crustal subsidence; conditions which, although they obtained at other geological periods over relatively small areas, were never repeated on so vast a scale. Having regard to the estimates of coal deposits in Cretaceous and Tertiary strata, published in our first International Coal Census, the "Report on the Coal Resources of the World",[1] it would appear that we might reasonably link the Cretaceo-Tertiary Period with the Carboniferous in respect of these peculiar and widely prevalent coal-making conditions. For I find that of the actual and probable reserves of coal in the world, according to our present state of knowledge, about 4½ million million tons of bituminous and anthracite coal exist, the vast bulk of which is of Carboniferous age; while there are about 3 million million tons of lignites and sub-bituminous coals, mostly of Cretaceous and Tertiary age.

When we look to the geological distribution of *petroleum*, we note that it is to be found in rocks of practically every age in more or less quantity, but that it occurs *par excellence*, and on a great commercial scale, in rocks of two geological periods (to a smaller extent in a third); and it is significant that these two periods are the great coal-making periods in geological history—the Carboniferous and the Cretaceo-Tertiary. . . .

The world's production of petroleum has trebled itself within the last fifteen years. In 1914 the United States of America produced 66·36 per cent, and North and South America together nearly three-fourths of the world's total yield; while the British Empire

[1] Report on "The Coal Resources of the World", for the Twelfth Intern. Geol. Congress, 1913.

(including Egypt) produced only a little more than 2 per cent. In the near future Canada is likely to take its place as a great oil- and gas-producing country, for large areas in the middle-west show promising indications of a greatly increased yield. But Mexico is undoubtedly the country of greatest potential output. Its Cretaceous and Tertiary strata along the Gulf Coastal Plain are so rich that it has been stated recently on high authority that "a dozen wells in Mexico, if opened to their full capacity, could almost double the daily output of the world".[1]

As is well known, natural supplies of petroleum are not found in the British Isles on a commercial scale; but for many years oil and other valuable products have been obtained from the destructive distillation of the oil shales of the Lothians. If Mr. Cunningham Craig is right in his views recently expressed,[2] these shales, or rather, their associated freestones, have been nearer to being true petroliferous rocks than we thought; for he believes that the small yellow bodies, the so-called 'spores' in the kerogen shales, are really small masses of inspissated petroleum absorbed from the porous and once petroliferous sandstones with which the shales are interstratified.

If recent experiments on peat fulfil the promise they undoubtedly show, we shall have to take careful stock of the peat-bogs in these Islands. It is well known that peat fuel has been manufactured in Europe for many years. But my attention has been called to a process for the extraction of fuel-oil from peat, which has been tried experimentally in London, and is now about to be launched on a commercial scale, utilizing our own peat deposits, like those of Lanarkshire and Yorkshire. . . .

It is sometimes asked whether the adoption of mineral oil as a power-producer is likely to supplant coal, and thereby seriously reduce the output of that mineral. The world's yield of petroleum will doubtless go on increasing at a very great rate; but from the experience gained in some of the fields in the United States and Eastern Canada, it seems unlikely that this increase can continue for a very long period. Practically complete exhaustion of the world's supply is to be looked for within 100 years, says one authority.[3] Even if the output rose to ten times the present yield, it would represent only about half the present world output of coal, and it is practically certain that so high a yield of oil could not be maintained for many years. Owing to the almost certain rapid increase in the output of coal, estimates made by the same authority already quoted indicate that the total production of petroleum could never reduce the world's output of coal by more than about 6½ per cent.[4]

For us, and probably for those of the next generation, the geology

[1] Ralph Arnold, "Conservation of the Oil and Gas Resources of the Americas": *Econ. Geol.*, vol. xi, No. 3, p. 222, 1916.
[2] Institution of Petroleum Technologists, April, 1916.
[3] H. S. Jevons, *British Coal Trade*, 1915, p. 710.
[4] Ibid., p. 716.

of petroleum will continue to be of immense practical importance; but coal will doubtless remain our great ultimate source of power.

An obligation rests upon us to see that the oil resources of the British Empire and of territories within our influence are explored, if possible, by British geologists, with all the specialized knowledge that can be brought to bear; and I am glad to think that the University of Birmingham and the Imperial College of Science and Technology, London, with this end in view, are doing pioneer work in giving a systematic and specialized training to our young petroleum technologists. . . .

Underground Water.

Since the year 1856, when the Frenchman, Darcy, attempted by a mathematical formula to express the law governing the transmission of water through a porous medium, nearly all investigation upon this important engineering question has been carried on in the United States; and many of the results have been published in the valuable Water Supply and Irrigation Papers of the United States Geological Survey. Particular reference should be made to the work of Hazen, King, Darton, and Slichter, the last of whom has given us the clearest and most convincing explanation of the behaviour of water percolating through a porous rock. He and his co-workers have experimentally investigated the factors which determine the underground flow, and expressed their relationship by mathematical formulæ; and they have made it clear, by careful measurement extended over long periods, that the rate of flow through average porous water-bearing rocks and under ordinary pressure gradients is extremely small, something like a mile a year, or even less.[1]

Geologists who are in touch with the application of these principles to such engineering matters as water-supply, sewage, and drainage will readily appreciate the great value of such researches. At the same time, one must reluctantly confess that, with few exceptions, the investigations have not been adequately grasped and utilized in present-day engineering practice in this country. As to their geological bearing, we have only to be reminded of the important processes of solution, cementation, and fossilization in rocks in order to comprehend the value of a just estimate of the behaviour of this vast and slow-moving chemical medium in which the superficial rocks of the crust are immersed. . . .

The conditions are so complex and the controlling factors vary so much in different river-basins that it is impossible to obtain for the whole country anything like an accurate and reliable expression for the relationship between rainfall, percolation, and run-off. The interminable and costly legal wrangles during the passage of a Water Bill through Parliament bear witness to the truth of this statement. What is needed is a continuous record in the different catchment areas of the country of observations on river discharge, percolation, and so forth, extended over many years. Fortunately, our rainfall observations, thanks to the British Rainfall Organization, are now

[1] Slichter, Water Supply Paper No. 67, U.S. Geol. Surv.: "The Motions of Underground Waters."

or could be made, ample for this purpose. But except for attempts by local water companies and corporations to obtain the data I have referred to, there exists no public control to deal with the matter.

In 1906 a Committee of the Royal Geographical Society, with Dr. Strahan as Chairman, and with the aid of a grant from the Royal Society, undertook to investigate river discharge, suspended and dissolved matter, rainfall, area, and geological conditions in some specially selected river-basins. The final report, which has now appeared, dealing with the Severn above Worcester, the Exe, and the Medway, constitutes a most valuable record. . . .

It will be obvious to all geologists that important theoretical questions, such as the rate of denudation and deposition, and vital engineering matters, such as the position and permanency of harbour works, would be greatly assisted by exact quantitative estimates of the material carried down by rivers.

In 1878 Joseph Lucas urged the importance of a Hydro-geological Survey of England, and the Royal Commission on Canals and Waterways in their final report in 1909 recommended the appointment of some public authority to do for the whole country what this Committee has so admirably done for these three river-basins.

Organization of Expert Knowledge.

We are reminded by the report of a later Royal Commission—that on Coast Erosion in 1911—that systematic observations and the collation and organization of geological and engineering knowledge are urgently needed in connexion with the protection of our coasts and the reclamation of new lands. For it will be remembered that the Commission found that during the last thirty-five years the gain of land, as shown by Ordnance Survey maps, has been more than seven times the loss by erosion.

Here, again, the British Association may reflect with pride that it paved the way for this national inquiry. For many years its Committee on Coast Erosion gathered and collated evidence on erosion, and induced the Admiralty to instruct the Coastguard to observe and report upon changes that take place from time to time. . . .

Is it not abundantly clear that in economic geology, as in the case of other applied sciences, we must rely in the future less upon chance individual effort and initiative? We must concentrate, centralize, and organize; and at every stage we shall need expert control and advice as regards those larger scientific issues of national importance which have a direct practical bearing.

II—The Mapping of the Earth, Past, Present, and Future. Being an abridged report of Address to the Geographical Section (E), British Association, Newcastle. By Edward A. Reeves, F.R.A.S., F.R.G.S., President.

AFTER a brief allusion to the increasingly important part Science had been called upon to play in the present great crisis and the value of a more thorough and general scientific training, the President

pointed out the various ways the present War will affect the map-maker, owing to the surveying and arranging of new boundaries, etc., as after all is over our present maps and atlases will have to be very largely revised and brought up to date.

He divided his Address into the following headings:—

1. A brief general summary of what has been done in the past towards the mapping of the earth's surface.
2. A sketch of how things stand at the present time.
3. A few remarks upon future work, specially as regards instruments and methods.

Commencing with a historical sketch of geographical exploration and representation of the surface features of the earth from as early a date as B.C. 276, the President stated that—

It was not until the latter part of the fifteenth century, the time of the great Portuguese and Spanish discoveries, that any real advance was made, but then Europe seemed to awake from a long sleep, and a grand new start was made.

One of the first acts of King John II of Portugal (1481–95), whose memory deserves to be equally held in respect with that of his great uncle Prince Henry, was the calling together of the Committee, or 'Junta', of learned men to consider the best means of finding the latitude when the Pole Star was too low to be of service, to decide upon the most approved form of instrument for the taking of observations, and to furnish suitable tables of declination, etc., for the computations. Equipped with the new tables, which may, perhaps, be considered the first Nautical Almanac, and the simplified astrolabe, the Portuguese navigators started on the famous voyages, with a much better chance of properly fixing positions than their predecessors. The Vernier had not yet been invented, and so the difficulty of obtaining accurate readings of the circles was still considerable. To overcome this difficulty it was decided to construct astrolabes with very large circles, and the instrument carried by Vasco da Gama in his famous voyage round the Cape in 1497 had a circle which measured just over two feet in diameter. . . .

The difficulty of taking anything like accurate observations at sea was for centuries a very serious one, and long before the invention of the reflecting quadrant or sextant many were the attempts to devise some instrument for accomplishing this. . . .

It was not until the ingenious invention of the reflecting octant, suggested first of all by Sir Isaac Newton, that anything approaching accuracy was possible. Hadley's quadrant was the first of such instruments to be put into actual use, but there is no doubt that the idea should be ascribed to the famous Sir Isaac Newton, although the instrument was probably independently invented by Hadley.

With the invention of the sextant, or its predecessors the octant and quadrant, rapid progress was made in improvements in navigation and surveying instruments.

The introduction of the Nonius by Peter Nuñez in the middle of the sixteenth century, and later of the Vernier by the Frenchman Francis Vernier, which, owing to its simplicity, soon superseded the

former, were of great importance, since it was no longer necessary to construct the enormous large arcs and circles which had hitherto been indispensable to give anything like accuracy.

The magnetic compass not only made an enormous difference in navigation and exploration by sea, since it enabled the sailor to launch boldly out into the unknown oceans with confidence, but it soon began to leave its mark on land-surveying and geographical exploration. Much has been written on the invention of the compass, and many have been the disputes upon the subject, but it was certainly in use in Mediterranean countries of Europe as early as the twelfth and thirteenth centuries. The date when it was first used for land-surveying is not known exactly, but in Europe it was probably about the early part of the sixteenth century. . . .

The surveying equipment of the pioneer explorer of early days, say, of from twenty to sixty years ago, usually consisted of a sextant and artificial horizon, a chronometer or watch, prismatic compass, boiling-point thermometers, and aneroid. With the sextant and artificial horizon the astronomical observations for latitude and longitude were taken, as well as those for finding the error of the compass. The route was plotted from the compass bearings and adjusted to the astronomically determined positions. The latitudes were usually from meridian altitudes of the sun or stars, and longitudes from the local mean time derived from altitudes east or west of the meridian, compared with the times shown by the chronometer, which was supposed to give Greenwich mean time.

The sextant, in the hands of a practical observer, is capable of giving results in latitude to within 10″ or 20″, provided it is in adjustment, but the difficulty is that the observer has no proper means of testing for centering and graduation errors.

The great drawback to the sextant for survey work is that it is impossible to take accurate rounds of horizontal angles with it, since, unless the points are all on the same level, the angles must be too large. It is essentially a navigator's instrument, and nowadays has been almost entirely superseded by the theodolite for land-surveying.

As regards the longitude, the difficulty was always to obtain a steady rate for the chronometer, owing principally to the unavoidable oscillations and concussions met with in transit. Formerly it was customary to observe lunar distances for getting the Greenwich mean time instead of trusting to the chronometers, but these, even with the utmost care, are very unsatisfactory.

In more recent years the occultation of a star method of finding the Greenwich mean time superseded almost entirely the lunar distance, but all of these so-called 'absolute' methods of finding longitude are fast becoming out of date since the more general introduction of triangulation and wireless telegraphy.

Heights of land were usually obtained by the boiling-point thermometer or aneroid.

This, then, was the usual equipment of the pioneer. With such an outfit the greater part of the first mapping of Africa and other regions of the world was carried out, with results that were more or

less reliable according to the skill of the explorer and the time and opportunities at his disposal.

In recent years considerable improvement has been made in the instruments and methods of the geographical surveyor: the introduction of the Invar tape for the measuring of the baselines, the more general application of triangulation, the substitution of the theodolite for the sextant, the use of the plane-table for filling in the topographical details of the survey, the application of wireless telegraphy to the determination of longitudes, these and other improvements have all tended to greater accuracy and efficiency in geographical and topographical mapping, so that in many respects the rough approximate methods of the earlier explorers are fast being superseded by instruments and methods more in keeping with modern requirements in map-making.

Still, the principle underlying all surveying is the same, and the whole subject really amounts to the best and most accurate methods of measurement with a view to representing on a plane, on a greatly reduced scale, the leading features of a certain area of the earth's surface in their relatively correct positions; and so it resolves itself into geometrical problems of similar angles and proportional distances. This being the case, it is clear that it becomes in the main a question of correct angular and linear measurements, and all the improvements in survey methods have had for their object the increased accuracy of accomplishing this, together with greater facility for computing the results. . . .

So far what I have said has had chiefly to do with some of the earlier attempts at surveying and map-making, and the instruments and methods by which these have been carried out; and I will now try to give you an outline of what has been done in comparatively recent times, and state briefly the present position of various parts of the world as regards the condition of their mapping and the survey basis upon which their maps depend.

Little by little civilized man, by his daring, his love of adventure, and the necessities of events and circumstances, has penetrated into the unexplored parts of the earth and pushed back the clouds and mists that so long shrouded them from his knowledge, until at the present time the regions that are entirely unmapped are very few indeed, and do not amount to more than about one-seventh of the whole land-surface of the globe, including the unexplored areas of the Polar regions, which may be either land or water. Not content with a mere vague acquaintance, he has striven for greater accuracy, and has turned to various branches of science and called them to his aid, in order that he may obtain more correct knowledge and a better comprehension of the earth's features. To enable him to fix with definiteness the position of places upon its surface, map out the various land-forms, and obtain their accurate measurements, he has consulted the astronomer and mathematician. Commencing, as we have seen, with the rudest instruments and measuring apparatus, these, as greater accuracy was required, have gradually been improved, until the present-day appliances and equipment of a surveyor are a wonder of refinement and delicacy. . . .

I have attempted to form an estimate of the condition of the world's surveys as represented by the differently tinted areas on the maps for 1860 and 1916;[1] and, taking the total area of the land-surface of the earth, together with the unknown parts of the Arctic and Antarctic regions which may be either land or water, to be 60,000,000 square miles, I have obtained the following results:—

	1860		1916	
	Sq. Stat. Miles.	Proportion to Whole.	Sq. Stat. Miles.	Proportion to Whole.
1. Mapped from accurate topographical surveys based on triangulation or rigorous traverses	1,957,755	= 0·0326 or roughly $\frac{1}{30}$	8,897,238	= 0·1482 or roughly $\frac{1}{7}$
2. Mapped from less reliable surveys, chiefly non-topographical	2,017,641	= 0·0336 or roughly $\frac{1}{30}$	5,178,008	= 0·0866 or just over $\frac{1}{12}$
3. Mapped from route traverses and sketches	25,024,360	= 0·4170 or roughly $\frac{2}{5}$	37,550,552	= 0·6258 or little less than $\frac{2}{3}$
4. Entirely unsurveyed and unmapped	30,997,054	= 0·5166 or just over $\frac{1}{2}$	8,350,794	= 0·1391 or little less than $\frac{1}{7}$

These proportions can perhaps be more clearly seen from the following small diagram.

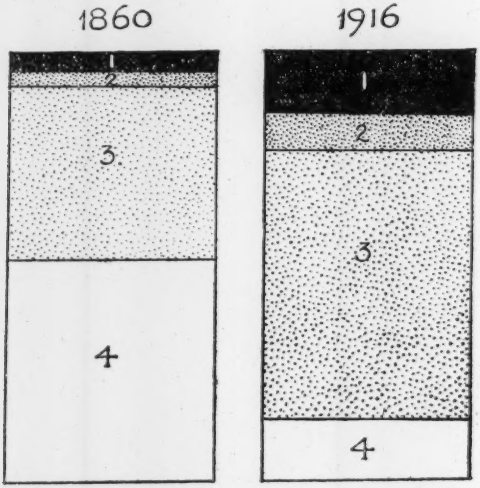


Diagram showing the relative proportions of the earth's surface in 1860 and 1916, which are—1, fully mapped; 2, partially mapped; 3, slightly mapped; and 4, not mapped in the two periods referred to.

It is plain that with the same rate of progress as that of the past sixty years or so it would take just over four hundred years more

[1] The two maps have not been reproduced from Mr. Reeves' Address, but the small diagram is given and shows the areas mapped and unmapped and their relative proportions.

to complete the accurate trigonometrical surveying and topographical mapping of the earth's land-surface, including the parts of the Polar regions that may possibly be land—that is, the 60,000,000 square miles which we have taken for this total area; but this will certainly not be the case, since the rate at which such surveys have been carried out has been greatly accelerated during recent years, owing to the rapidly increasing demands for accurate topographical maps, improvements in methods, and other causes, so that it will possibly not be half this time before all the parts of the earth's surface that are likely to be of any use to man as settlements, or capable of his development, are properly surveyed and mapped. There are, of course, regions, such as those near the Poles and in the arid deserts, that are never likely to be accurately triangulated and mapped to any extent, and it would be mere waste of time and money to attempt anything of the kind. . . .

Many and varied have been the influences that have led to the surveying and mapping that have already been accomplished, and it would be interesting if we had time to analyse them. Among the preliminary surveys, I think it would be found that military operations would hold an important place. Many an unexplored region has been mapped for the first time as the result of frontier expeditions, such as those of the frontier regions of India and parts of Central and South Africa, while the need of a more exact acquaintance with the topographical features for military requirements have frequently led to more exact trigonometrical surveys. Our own Ordnance Survey is indeed an example of this, for in the first place it resulted from the military operations in Scotland in the latter part of the eighteenth century.

Among other causes that have resulted in surveying and mapping might be mentioned the delimitation of boundaries, commercial or industrial undertakings, such as gold-mining and land-development, projects for new railways, all of which have at times been fruitful in good cartographical results. Nor must we forget Christian missions. The better-trained missionary has always recognized the importance of some sort of a survey of the remote field of his operations, and the route to it, if for no other reason, with a view to the good of his fellow-workers and those who come after him; and in the earlier days especially perhaps most of all pioneer mapping was done by the self-sacrificing service of the missionary. We have only to think of such men as Moffat, Livingstone, Arnot, Grenfell, and others of the same sort to be reminded of the debt due to the missionary from all interested in geographical mapping. . . .

The future surveyor will be in a much better position than his predecessors, not only on account of the improvements in instruments and apparatus for his work, but because, in many parts, a good beginning has been made with the triangulation to which the new surveys can be adjusted. In Asia a considerable amount of new work of this kind has been done over the frontier of India in recent years by the Survey of India, among the more important of which is the connecting of the Indian triangulation with that of Russia by way

of the Pamirs. The many boundary surveys that have been carried out in Africa, the triangulations of Egypt, the Soudan, East and South Africa, and other parts of the continent are well advanced, and will be of the utmost value to the future surveyor. One of the most important lines is the great triangulation which, it is hoped, will some day run across the continent from south to north, from the Cape to Egypt. Owing to the energies of the late Sir David Gill, this important chain of triangles has already got as far as the southern end of Lake Tanganyika; the part to the west of Uganda near Ruwenzori has also been finished, and it now remains to carry the chain through German East Africa and down the Nile Valley. The latter, it is hoped, will by degrees be accomplished by the Soudan and Egyptian Survey Departments, although it may be delayed for some years yet; and the former, which was to have been undertaken by the Germans, it is hoped will after the War be accomplished by British surveyors, through—not German East Africa—but newly acquired British territory. Running right through parts of Africa that are but imperfectly mapped in many districts, the stations of this triangulation will be invaluable for the adjustment of any network of triangulation for future surveys in the interior, and, indeed, has already been utilized for the purpose.

The carefully carried out boundary surveys between various countries of South America will be of the greatest assistance in future exploration and survey in the interior of that continent, wherever they are available, while the Survey Departments of Canada and the United States are doing excellent work and extending their surveys far into the imperfectly mapped regions of North America. So, altogether, the surveyor of the future will soon have a good foundation of reliable points to work from. It is important to remember that running a chain of triangles across a country, though important as a framework, does not constitute a map of the country; and what is wanted, at any rate in the first place, is a series of good topographical maps, based upon triangulation, showing the leading features with sufficient accuracy for the purposes of ordinary mapping, so that on scales of 1 : 250,000 or even 1 : 125,000 there is no appreciable error.

As regards instruments, the Astrolabe à Prisme is being increasingly used for taking equal altitude observations with most excellent results, but at the present time the 5 in. transit micrometer theodolite, already referred to, is perhaps all that is required for general work. It has now been thoroughly tested and found most satisfactory. As regards smaller instruments, there is the 4 in. tangent-micrometer theodolite, and for rapid exploratory survey, where weight is a great consideration, a little 3 in. theodolite has been found useful.

For baseline measurement the Invar tape should be taken on all serious work, and for filling in the topographical features a good plane-table is doubtless the instrument to use. In mountainous regions and in some other special conditions photographic surveying doubtless has a future before it, and in military operations when the photographs are taken from aircraft it has proved itself invaluable; but in ordinary surveying it is, I think, not likely to take the place of well-established methods. The introduction of wireless telegraphy

for the determination of longitude is likely to increase in usefulness. Good examples of the work done with it have lately been given in the *Geographical Journal* and elsewhere.

REVIEWS.

I.—The Skull of *Ichthyosaurus*, studied in Serial Sections. By Professor W. J. Sollas, F.R.S. Phil. Trans., ser. B, vol. ccviii, pp. 63–126, with 22 text-figures and 1 plate, 1916.

In this paper Professor Sollas gives a detailed account of the results of his method of serial sections applied to the skull of an Ichthyosaur, probably a variety of *I. communis*. No less than 520 sections were prepared, photographed, and modelled in wax, and the resulting reconstruction gives a clearer idea of the details of the structure of the skull than has hitherto been attainable. The relations of the roofing bones of the skull, that unite by extensively overlapping sutures, are now for the first time made clear, and the presence of a septo-maxillary element is demonstrated; in the lower jaw the presence of the *goniale* (prearticular) is shown.

Professor Sollas has met with the usual difficulty in determining the relative position of the bones forming the auditory capsule, the existence during life of extensive areas of cartilage between them resulting in their displacement when putrefaction took place. He puts the pro-otic low down, below the opisthotic and in contact with the basi-occipital, a position which seems inconsistent with the share which this element must have taken in helping to enclose the auditory labyrinth.

Another point of special interest is the presence of a series of structures which are regarded as the remnants of a hyobranchial apparatus. Not only is this interpretation an improbable one, but the facts seem capable of a simpler explanation. The elements (marked *a* and *b* in fig. 17) which are regarded as branchials closely resemble in form the upper bifurcated ends of cervical ribs, while those marked *s.d.* may be halves of a neural arch. Professor Sollas admits that these bones lie dorsal to the hyoids, and furthermore notes the presence in the specimen of the displaced centra of the atlas, axis, and third cervical, so that it therefore seems at least possible that the presumed branchial bones are displaced appendages of these vertebræ.

The paper is illustrated with twenty-two text-figures, mostly of sections of the skull, and a plate giving figures of the basi-occipital and basisphenoid, both of the reconstructed skull and of other specimens. Some diagrammatic figures of the various bones might have been added with advantage.

The paper as a whole is a valuable contribution to our knowledge, and the author is to be congratulated on the successful application of his elaborate and laborious method of investigation to a fresh subject.

C. W. A.

II.—Types of Prismatic Structure in Igneous Rocks. Journ. Geol., vol. xxiv, pp. 215–34, 1916.

THERE are several types of prismatic structure, due to different causes. Of these the most important are attributed to (1) thermal contraction in the crystallized rock, (2) convectional circulation of the still liquid magma, (3) internal expansion. The study of the prismatic structures in rock-masses may yield useful information as to the conditions under which the rock was formed: since quantitative data are very scarce, it is highly desirable that experimental work in this direction should be carried out; this would necessitate the handling of larger masses of rock than are generally dealt with in laboratory experiments. It is probable that much could be learned from a careful study of such structures in the field.

R. H. R.

III.—The Age of the Killarney Granite. Department of Mines, Canada, Museum Bulletin No. 22, 1916.

IN this paper Mr. W. H. Collins brings forward evidence to show that the Killarney batholith on the north side of Lake Huron is intrusive into sediments of the Bruce and Cobalt series of the Huronian system. These have undergone a very high degree of deformation and metamorphism, but their correlation with the more normal rocks is established. The granite is not foliated and approaches a syenite in composition, owing to scarcity of quartz, and it contains recognizable xenoliths of the Espanola quartzite and other rocks, thus establishing its post-Huronian age. The disturbance and intrusion were completed long before Ordovician time, and must therefore be regarded as belonging to the later pre-Cambrian.

R. H. R.

IV.—The Rocks and Minerals of the Croydon Regional Survey Area. By G. M. Davies. Proc. and Trans. Croydon Nat. Hist. and Scient. Soc., 1915–16, pp. 53–96.

FOR some years past this society has been conducting a regional survey of East Surrey and West Kent. The results of much patient work on the rocks of the district are here presented. The methods adopted are based on 'panning' of the material with subsequent separation in heavy liquids, and the data obtained are given in a quantitative form. The minerals found are those usually present in sedimentary rocks of all ages, and it is clear that there has in all cases been a passage of mineral grains from one bed to another, so that there is less variation in composition than might be expected. Andalusite is found to be fairly common in Cretaceous strata as well as in the Tertiary sands, while the occurrence of monazite is of considerable interest. As might be expected, zircon, tourmaline, and kyanite are almost universally present in the heavy residues, while staurolite and garnet are almost equally common.

R. H. R.

V.—Metallogenetic Epochs in the Pre-Cambrian of Ontario. By W. G. Miller and C. W. Knight. Trans. Roy. Soc. Canada, ser. III, vol. ix, pp. 241–9, 1915.

THE enormous economic importance of the ore bodies of Ontario has enabled geologists to study the Pre-Cambrian rocks there disclosed with very special intimacy. While only a few years ago Lindgren found it advisable to consider the Pre-Cambrian era of ore deposition as a whole, the authors of the paper before us have distinguished four major epochs of metallogenesis. The following table summarizes the main conclusions:—

Keweenawan.—Basic intrusions passing in places into acid rocks.
1. Silver, cobalt, nickel, and arsenic at Cobalt.
2. Nickel and copper at Sudbury.
3. Gold deposits (not now productive).

Animikean.—Chemical deposition of 'iron formations'.

Algoman.—Intrusions of granite.
1. Gold at Porcupine and many other localities.
2. Galena, zincblende, and fluorspar.

Basic intrusions of post-Timiskamian age.
1. Nickel and chromite.
2. Magnetite and titaniferous magnetite.

Timiskamian.—Chemical deposition of 'iron formations' (of minor importance).

Laurentian.—Intrusions of granite (which probably gave rise to ore deposits since removed by excessive erosion).

Grenville.—Chemical deposition of 'iron formations'.

Keewatin.—Extrusions of basic volcanic rocks.

The table brings out the importance of igneous activity in the formation of ore deposits, the succession including three cycles of intrusion each beginning with basic and concluding with acid rocks. At present the 'iron formations' of Animikean and Timiskamian age in Ontario are not productive, but in Michigan they are the annual source of millions of tons of iron-ore.

A. H.

VI.—Guide-book of the Western United States. Part C: The Santa Fe Route. Bull. 613 U.S.G.S. pp. 194. Washington, 1915.

THIS book, which is one of a series of four dealing with the main railway routes in the western United States, is issued with a view to furthering the "see America first" movement, by providing a handy book which will give the traveller all the important features, both geological and geographical, in order, as he journeys along the railway. The book is divided up into sections, each with its own map showing the railway and the country from ten to fifteen miles on either side of it, with contours and geological boundaries. Each section covers about sixty miles, the whole route stretching from Kansas City to Los Angeles, and including a journey to the Grand

Cañon of the Colorado. A short history is given of the different states and towns through which the line passes, as is also an account of their agricultural and mineral resources, while the geological and geographical features are described in some detail in their order. The book is illustrated by a series of excellent photographs and many geological sections; it has also a useful index of the stations.

W. H. W.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 8, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The President referred to the loss which the Society had sustained during the recess by the decease of its Treasurer, Mr. Bedford McNeill, A.R.S.M., M.Inst.M.M., A.M.Inst.C.E. He spoke of Mr. McNeill's eminence in his profession, and of the services that he had rendered to the Society as a Member of Council for many years and as Treasurer since 1912. The President mentioned that the Society was well represented at the funeral, and added that he felt sure that the Fellows would associate themselves with the resolution of condolence and sympathy which the Council had addressed to Mrs. McNeill.

The following communication was read:—

"*Aulina rotiformis*, gen. et sp. nov., *Phillipsastræa hennahi* (Lonsdale), and the genus *Orionastræa*." By Stanley Smith, B.A., D.Sc., F.G.S.

The primary object of the present communication is a description of a new and interesting coral genus of colonial habit, *Aulina*, obtained from the highest limestone that can be associated with the Lower Carboniferous—the Fell Top Limestone of Northumberland and its equivalent horizon in Teesdale, the Botany Beds.

Since this form has been confounded with another Carboniferous species well known under the name of '*Phillipsastræa radiata* (S. Woodward)', it has been found advisable, in fact necessary, to extend the original scope of the paper so as to include a revision of the genus *Phillipsastræa* and a description of '*Ph. radiata*' and its allies, which I have grouped together under a new generic name, *Orionastræa*. Several type-specimens, including that of *Phillipsastræa hennahi* (the genotype of *Phillipsastræa*), are described and figured.

The new genus from the Fell Top Limestone is a very distinctive form, on account of the remarkable annular wall developed within the theca, and may prove of considerable value as a zonal index.

The corallum in this genus, as also in *Phillipsastræa* and in *Orionastræa*, represents a stage in colonial development in which the epitheca of the individual corallites has entirely disappeared, and these are consequently united by their dissepimental tissue—a type of colony to which the term 'Astræiform' may be applied.

Diagnoses.—*Aulina rotiformis.*—The corallum is massive, and the corallites are united by their extrathecal tissue; all the septa dilate at the theca, and those of the major cycle again dilate at their axial edges, in such a manner as to fuse together, and so build a cylindrical wall or tube within the theca. The structure of the form is in most respects similar to that of *Phillipsastræa*, but it appears to carry forward the septal characters peculiar to that genus to a further stage of development.

Phillipsastræa.—The corallum is composite and massive; the corallites are united by their dissepiments, or are only separated by a thin epitheca; in the former case the septa are often confluent. Major and minor septa dilate at the theca; the latter terminate there, and the major septa attenuate and advance into the intrathecal region, and there often dilate again at the axial edge. The central part of the corallite is occupied solely by tabulæ.

Orionastræa.—The characters of this genus are essentially those of *Lithostrotion*, but of a modified form. The corallum is composite and massive, and the corallites are either defined by a thin epitheca, or, in the more typical instances, by no epitheca at all; in this latter case the corallites are united by their dissepiments and the septa are confluent.

The distinguishing characters of the three species recognized and described are as follows:—

1. *O. ensifer* (Edwards & Haime) .	Septa not confluent .	Columella present.
2. *O. phillipsi* (McCoy)	Septa confluent . .	Columella present.
3. *O. placenta* (McCoy)	Septa confluent . .	Columella absent.

II.—Mineralogical Society.

Anniversary Meeting, *November* 7, 1916.—W. Barlow, F.R.S., President, in the Chair.

The following were elected Officers and Members of Council: President, Mr. W. Barlow, F.R.S.; Vice-Presidents, Professor H. L. Bowman, Mr. A. Hutchinson; Treasurer, Sir William P. Beale, Bart., K.C., M.P.; General Secretary, Dr. G. T. Prior, F.R.S.; Foreign Secretary, Professor W. W. Watts, F.R.S.; Editor of the Journal, Mr. L. J. Spencer; Ordinary Members of Council, Captain W. Campbell Smith, Dr. J. W. Evans, Dr. F. H. Hatch, Mr. J. A. Howe, Mr. T. V. Barker, Mr. G. Barrow, Professor C. G. Cullis, Mr. F. P. Mennell, Mr. H. Collingridge, Mr. T. Crook, Dr. G. F. Herbert Smith, Dr. H. H. Thomas.

The following papers were read: Dr. J. W. Evans: The Combination of Twin Operations. The question of complex twin-crystals in which two distinct laws of twinning are represented was dealt with.

A distinction was made between cases in which the twin-axes are parallel or at right angles, and those in which they are inclined to one another obliquely. In the former the result of the combination is itself a twin operation, while in the latter it is a rotation, the direction of which depends on the order in which the operations are applied; it is in some cases combined with an inversion.—Dr. J. W. Evans: A Modification of the Kohlrausch Method of determining Refractive Indices. The observing instrument is a microscope placed vertically and fitted with a Bertrand lens. An immersion theodolite stage of the Klein type is used, so that the substance under investigation may be rotated beneath a liquid of higher refractive index about two axes, the first at right angles to the optical axis of the instrument, and the second at right angles to the first and to the plane surface of the object. This is observed through the natural surface of the liquid and rotated in either direction until the position of total reflection is reached. By rotation of the object about the second axis the refractive indices in all directions parallel to its plane surface may be determined, and the values of the principal refractive indices thus obtained.—A. Holmes and Dr. H. F. Harwood: The Basalts of the Brito-Arctic Province. The basalts from Hare Island, which were collected by Thomas Reid in 1855, include six varieties, of which four are free from olivine and carry silica among the amygdale minerals, and the remaining two contain olivine and are without free silica. All the rocks are rich in titaniferous magnetite, and analyses indicate that their most noteworthy feature is the unusual abundance of titania. The analyses cannot be closely matched except by those of basalts from Scoresby Sound, Iceland, the Faröe Islands, and the west of Scotland. This paper is the first of a series in which the authors hope to describe rocks from all the important localities within the province.—Miss N. Hosalie exhibited models of crystals constructed by herself.

OBITUARY.

BEDFORD McNEILL

A.R.S.M., M.Inst.M.M., Assoc.Memb.Inst.C.E.,
Treasurer Geol. Soc. Lond., etc.

By the death of Mr. Bedford McNeill, at the comparatively early age of 55, the mining world has lost one of its most distinguished men. Mr. McNeill took his diploma at the Royal School of Mines in 1880, and after considerable experience in various parts of Europe and America became famous as the compiler of "the Telegraphic Code" that bears his name. He gave his time freely to the service of scientific societies, and besides being a Fellow of the Institute of Chemistry and a Member of the Iron and Steel Institute, he was President of the Institution of Mining and Metallurgy 1913–14, and Treasurer of the Geological Society from 1912 until the time of his death.

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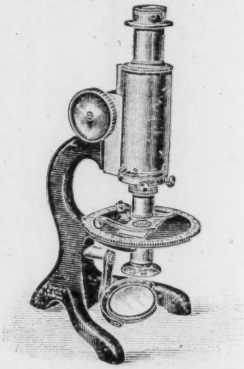

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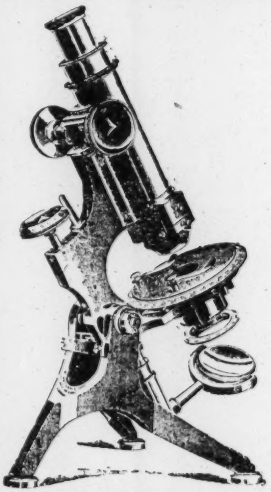

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